INSTRUMENTATION AND SENSING LABORATORY

In-Depth Laboratory Review

February 26 - 27, 1997

Natural Resources Institute
Beltsville Agricultural Research Center
Agricultural Research Service, USDA
Building 303, BARC-East
Beltsville, MD 20705-2350

CONTENTS

A. AGENDA

Building 303, BARC-East
Conference Room

Wednesday, February 26, 1997

8:30 - 8:35 AM	Introduction - G.R. Evans, Director, NRI
8:35 - 8:55 AM	Overview of the Laboratory - Yud-Ren Chen
8:55 - 9:25 AM	Initial Executive Session (Review Team, NPS, BAO, and ID/CD)
9:25 - 9:55 AM	Tour Facility
10:00 - 11:00 AM	Interview with Yud-Ren Chen
11:00 - 12:00 PM	Interview with Stephen R. Delwiche
12:00 - 1:00 PM	Lunch
1:00 - 2:00 PM	Interview with Bosoon Park, Renfu Lu, and Sukwon Kang
2:00 - 5:00 PM	Review Team Working Session
5:00 PM	Adjourn

Thursday, February 27, 1997

8:00 - 9:00 AM	Final Executive Session
9:00 AM	Adjourn

B. LIST OF MEMBERS OF REVIEW TEAM

Chair:

Dr. W. Fred McClure	Professor, Department of Biological and Agricultural Engineering North Carolina State University P.O. Box 7625 Raleigh, NC 27695-7625 Tel: (919) 515-6764 Fax: (919) 515-7760

Members:

Dr. William O. James	Director, Inspection Methods Development Division Food Safety Inspection Service, USDA Room 202, Annex Building 300 - 12th Street, S.W. Washington, DC 20250 Tel: (202) 720-3219 Fax: (202) 690-0824
Dr. James O. Reagan	Executive Director of Science and Technology National Cattlemen's Beef Association 5420 South Quebec Street P.O. Box 3469 Englewood, CO 80155 Tel: (303) 694-0305 Fax: (303) 694-2851
Dr. Kuan-Chong Ting	Chairman, Department of Bio-resources Engineering Rutgers University P.O. Box 231 New Brunswick, NJ 08903-0231 Tel: (908) 932-9753 or 9754 Fax: (908) 932-7931

C. MISSION AND VISION STATEMENTS

a. Mission Statement:

The mission of the Instrumentation and Sensing Laboratory is to develop new and innovative instruments and sensors that are useful to agriculture, by applying state-of-the-art technologies of electronics, optics, computer, pattern recognition, and artificial intelligence. The laboratory conducts basic research to characterize the physical, chemical, sensory, nutritional, and aesthetic properties of raw commodities. The laboratory devises nondestructive, non-invasive, and rapid systems to measure those attributes that comprise the postharvest quality of commodities.

b. Vision Statement:

Instrumentation and Sensing Laboratory (ISL) will maintain a center of expertise in measuring the quality of food and agricultural products with worldwide recognition. ISL will excel in developing improved, novel, rapid, nondestructive sensing techniques for agricultural products and food. ISL will maintain state-of-the-art equipment for optical, sonic (including ultrasonic), and mechanical measurements, state-of-the-art methods for signal and image processing and analyses, and state-the-art models of quality and measurement techniques. We will improve the engineering of quality measuring devices by a better understanding of the human perception of quality. Expertise in the genetics and physiology of quality will be provided by cooperation with other laboratories at BARC and elsewhere. We will remain at the forefront of nondestructive optical and ultrasonic quality sensing and extend these technologies.

D. RESEARCH ACCOMPLISHMENTS

1. **Classification of Poultry Carcasses By Vis/NIR:** A visible/near-infrared (Vis/NIR) spectrophotometer system was developed for on-line classification of wholesome and unwholesome carcasses. The Vis/NIR system can separate wholesome and unwholesome poultry carcasses on a moving shackle (60 or 90 birds/min), in room light or in a dark environment with very high accuracy. The unwholesome carcasses included cadavers and those with septicemia, airsacculitis, bruise, ascites, or tumor. The best results were obtained

with the 90 birds/min shackle speed and sensing in dark, with accuracies of 96.0 percent for classifying wholesome carcasses and 98.9 percent for classifying unwholesome carcasses.

2. **Classification of Poultry Carcasses By Multispectral Camera:** The spectral images of 540 nm and 700 nm wavelengths were found to be useful for separating unwholesome carcasses from the wholesome carcasses based on spectral image pixel intensity and the intensity distribution of the Fourier power spectrum. The best neural network classifier was obtained when spectral image pixel intensity of 540 nm and 700 nm wavelengths were combined and used as inputs. The accuracy of validation was 93.3 percent.

3. **Pilot-Scale Poultry Carcass Inspection System:** A pilot-scale instrumental inspection system for poultry carcasses was assembled and tested. The system includes a Vis/NIR spectrophotometer system for scanning the breast of the bird and a spectral imaging system which consists of two cameras with 540 and 700 nm filters for imaging the front of the bird and two additional cameras with identical filters for imaging the back of the bird. Both Vis/NIR system and spectral imaging system can operate up to 100 birds per minute.

4. **Beef Tenderness Measurements:** An instrument for ultrasonic shear force measurement for noninvasive beef tenderness evaluation was designed and fabricated. The results showed that ultrasonic velocity correlated with the elastic modulus of meat, which could be criteria for beef tenderness. A preliminary study indicated that NIR (1100-2500 nm) measurements at multiple locations on steaks could be useful for the prediction of tender/tough with success rates approaching 90 percent.

5. **Single Kernel Protein of Grain:** The mathematical models developed for predicting single kernel protein content from a near-infrared transmittance spectrum for six major U.S. classes of wheat demonstrated reasonably high accuracy. Typically, spectrally-determined kernel protein content could be predicted to within +/- 1.5 percent more than 95 percent of the time.

6. **NIR for Single Kernel Classification:** Neural network models on NIR transmittance spectra of single kernels were developed to predict wheat class on a kernel-by-kernel basis. For the most general model, incorporating all classes, the average accuracy was 95 percent. For the models using two classes of data (e.g., hard red winter vs. hard red spring) the accuracies were 97 to 100 percent.

7. **Single Wheat Kernel Classification by NIR Reflectance:** A study was conducted to determine the extent to which an NIR based system can classify individual kernels of wheat. The lower wavelength region (551-750 nm) was found extremely well suited for distinguishing the color differences between red and white wheats. Within a color group, the longer wavelength region (1100-2500 nm) was moderately well suited for winter vs. spring and hard vs. soft comparisons. Two-class model accuracy, defined as the proportion of correctly identified kernels of a known wheat class, was greatest (99 percent) when red and white classes (e.g., HRW vs. HWW) were compared. Accuracies declined to typically 78-91 percent when the two classes were of similar color (e.g., HRW vs. SRW or HWW vs. SWW).

8. **AOAC International Method on Protein Content in Bulk Wheat: Collaborative Study:** Four types of commercially available NIR instruments were studied, representing various combinations of wavelength region, mode of energy capture, method of energy dispersion, and treatment of spectral data. Results indicate that the whole-grain NIR technique has precision comparable to the two conventional methods, Combustion and Kjeldahl. The accuracy is comparable to the well-accepted levels for ground-grain instruments.

9. **Single Kernel Protein Content by NIR Reflectance:** More than 300 market samples of wheat have been analyzed kernel-by-kernel on a customized near-infrared (NIR) reflectance spectrophotometer. Five of the six major U.S. wheat classes (durum excluded) were analyzed. Results indicate that the NIR reflectance technique is capable of rapid and nondestructive evaluation of single kernel protein content, with an accuracy slightly poorer than the NIR method on bulk samples (the industry standard). The pooling of wheat classes to produce a general model does not diminish model accuracy.

10. **Rice Quality Assessment by NIR on Bulk White Rice:** Near-infrared (NIR) reflectance spectroscopy on whole milled samples was correlated with amylose content and protein content. The most accurate models were developed for protein content, amylose content, whiteness, transparency, and milling degree. Intermediate model accuracies were found for alkali spreading value, whereas the viscosity properties were not modeled well.

11. **Apple Firmness Measurement by Sonic Technique:** Sonic resonant frequency was found more closely related to the modulus of elasticity than to the traditional Magness-Taylor value.

The size of the fruit affects the resonant frequency, and the sonic stiffness coefficient, proposed earlier, compensates for the size effect. An algorithm using the sonic stiffness and other data related to the shape and location of resonance frequencies could classify apples as firm or soft with about 80 to 85 percent accuracy for most lots. Both prediction and classification were better for symmetrically shaped apples such as 'Golden Delicious' than for the more irregular 'Delicious.'

12. **Computer Simulation of Apple Vibrations:** Three-dimensional computer models were developed to simulate vibrations of apples. The second and third resonant frequencies were shown to relate to the apple's elastic modulus, size, and shape. Shape influenced resonant frequencies of all modes. The contact material, contact area between the fruit and instrument, and the input signal influence the vibrational characteristics of an apple but do not affect the second and third resonant frequencies. Optimal instrument design can be achieved by selecting a contact material slightly softer than apples, using a relatively large contact area, and using an impulse whose highest frequency is approximately equal to the maximum frequency of interest.

13. **Kiwifruit Firmness Measurements by Sonic Technique:** Sonic vibrational responses of kiwifruit over the range 0 to 2,000 Hz to the Magness-Taylor (MT) penetrometer test were compared. Sonic stiffness coefficients, based on sonic resonant frequencies and mass of the fruit, provided good to excellent classification of kiwifruit into two or three firmness categories based on MT maximum force values. A combination of amplitudes at several specific sonic frequencies also provided successful classification. Identification of soft kiwifruit was 89 to 96 percent accurate; while for firm kiwifruit, it was from 83 to 91 percent.

E. SUMMARY OF FINANCIAL RESOURCES

I. Base Funds

CRIS PROJECT TITLE	CRIS NUMBER	TOTAL DOLLARS
Development of Techniques for Instrument Grading and Inspection of Poultry and Beef Carcasses	1270-42440-001-00D	$651,507
Assessment of Single Grain Properties for Classification, Grading and End-use Suitability	1270-44000-005-00D	$286,287
Automated Firmness Classification of Apples	1270-44000-006-00D	$343,476

II. Temporary Funds (Grants)

CRIS PROJECT TITLE	CRIS NUMBER	TOTAL DOLLARS
Non-destructive Quality Evaluation of Fruits	1270-44000-002-04T	$ 90,000 (3 years)
Wheat Kernel Moisture During the Pre-milling Stage of Tempering	1270-44000-005-02T	$142,000 (2 years)

As Of: 08/27/96	Annual Resource Management Plan System	Page: 9
	Position Staffing Plan	Version FY94b
03-10-12-1270-45-00-00-00	BELTSVILLE AREA	701-1270-145
Instrumentation & Sensing	Natural Resources Institute	Instrument and Sensing Lab

Employee Name	Position Number	Position Title	Pay Plan & Grade(PPL)	Status	FTE	Salary	Footnote	BCD Date/ RA Exp Date
Chen, Yud Ren	1B938	Supervisory Agric. Engineer	GM-15(0)	PFT	1.00	101,900	L2	
Abbott, Judith	1B3285	Res. Hort.	GS-14(0)	PFT	1.00	78,300	L1	
VACANT	3B4327	Mech. Engr.	GS- 5(9)	PFT	1.00	38,650		10/01/96
Delwiche, Stephen	1B953	Agricultural Engineer	GS-13(0)	PFT	1.00	67,290	L1	
Kang, Sukwon	2B4228	Agricultural Engineer	GS-11(12)	TFT	0.00	0	P C1	08/03/98
Shaffer, Joyce	7B929	Phys. Sci. Tech.	GS- 9(9)	PFT	1.00	44,740		
Lu, Renfu	2B4813	Agr. Engr.	GS-12(12)	TFT	1.00	64,644	P	09/30/97
Park, Bosoon	2B4884	Agr. Engr.	GS-12(12)	TFT	1.00	71,580	P	07/31/98
Hruschka, William	3B4769	Mathematician	GS-12(12)	PFT	1.00	61,860		
VACANT	2B4000	Agricultural Engineer	GS-11(12)	TFT	1.00	50,930	P	10/01/96
~~[illegible]~~ Vacant	6B4549	Computer Specialist	GS-11(11)	PFT	1.00	57,010		
Nguyen, Minh	6B4612	Computer Program Analyst	GS-11(11)	PFT	1.00	50,870		
~~[illegible]~~ Vacant	3B4768	Electrical Engr.	GS- 9(9)	PFT	1.00	48,900		
VACANT	3B927	Instrumentation Engineer	GS- 9(11)	PFT	1.00	42,100		10/01/96
Brack, Thelma	9B922	Secretary (Office Automtn)	GS- 6(6)	PFT	1.00	33,650		
James, Clifton	0B4656	Engineering Technician	GS- 4(5)	TPT	0.50	10,100	Z1	
Patel, Devvrat	0B4668	Computer Clerk	GS- 4(5)	TPT	0.50	9,950	Z2	
Ou, Jeremy C.	0B7086	Engineering Technician	GS- 4(5)	TPT	0.50	9,850	Z1	
~~VACANT~~ Moulden, Nathlie	9B4507	Office Automation Assistant	GS- 4(5)	PPT	0.50	12,400		1/19/97 ~~10/01/96~~
					16.00	854,724		

Non Federal FTE

Type	FTE
Research Support Agreement	0.00
Support Service Contract	0.00
Donated	0.00
Revolving Funds	0.00
Other	0.00
	0.00

Footnotes:

C1 -Position/employee is officially assigned to and supervised within this organization, devoting 0 percent of work time, yet remainder of the time is spent in 593-1270-072.

P -Research Associate - Locally Approved, Locally Funded.

L1 -Level I SY (i.e., Lead Scientist/Project Leader).

L2 -Level II SY (i.e., Research Leader).

Z1 -Appt Expires 4/30/97

Z2 -Appt Expires 4/29/97

G. RESPONSE TO RECOMMENDATIONS FROM THE IN-DEPTH AND BRIEF REVIEWS

In-Depth Review Held On May 7-8, 1992

The following actions were taken in response to the report of a Review Team, which included the late Thomas L. Thompson (chair), Zachary A. Henry, David B. Funk, and Pat Basu, who conducted an in-depth review of ISL on May 7 - 8, 1992:

1. **Recommendation:** Adopt Total Quality Management principles, starting with jointly developing a vision, a mission statement for the laboratory, developing an emphasis on customer needs.

   Response: ISL has a mission and a vision statements, which were developed by the research engineers and scientists as a group. These statements adequately fit the research area (see page 1). ISL pursues the objectives of the projects approved by the ARS National Program Staff and the Director of the Natural Resources Institute. ISL staff participate in discussion in planning and execution of experiments and each staff member understands the objectives and approaches of each project. Group meetings are held to discuss the progress of the tasks assigned to each individual. All the CRIS projects have been developed to meet the needs identified by either governmental action agencies or an agricultural commodity industry. Each project is developed with final implementation of the research products at agricultural industries or action agencies in mind.

2. **Recommendation:** Establish a purpose and objectives statement that focuses on appropriate areas of technology into which the product-oriented research can fit. The vision for the lab should be long-range and permit the appropriate USDA-identified objectives to be accomplished, even as they change from year to year. When the purpose and objectives are established, be sure that each person (scientist-to-secretary) knows how he or she is contributing to the vision set forth. The broad purpose and objectives should be focused on technology areas and basic science areas, with short-term objectives in product areas. This might have to be sold to administrators who approve funding. However, if done correctly, we believe they would not only support the concept but would be excited about it.

   Response: As stated in the ISL mission and vision statements on page 4, long-term strategies and objectives of the laboratory were planned. The broad purpose and objectives are focused on technology areas and basic science areas, with short-term objectives in product areas. Each staff member is aware of the goals of this laboratory and the progress of the research.

3. **Recommendation:** Focus on selected technologies for in-depth development rather than trying to deal with too many technologies or computational approaches.

Response: ISL will continue evaluating specific areas to concentrate its efforts.

4. **Recommendation:** Attract new projects and personnel specifically to develop targeted technologies. This might include university faculty on temporary short- or long-term appointments.

   Response: See response to the fifth recommendation below.

5. **Recommendation:** Aggressively seek outside talent to enhance the laboratory through sabbaticals, visiting scientist programs, etc., to build the technology base more cheaply and quickly than by hiring and training new people.

   Response: ISL had success in seeking headquarters and National Research Initiative funded postdoctoral positions. ISL had a visiting scientist from the National Taiwan University who spent three months at ISL and a visiting scientist from Korea who spent their sabbatical at ISL. Currently (January 1997), ISL has 3 visiting scientists from Korea. ISL also has had Specific Cooperative Agreements with universities such as the University of Maryland, Washington State University, and The University of California at Davis. ISL has worked with the University of Rhode Island. Such agreements accomplish the objective of the recommendation when funds are available to establish Extramural efforts. Additional interactions, such as sabbaticals, with scientists and engineers outside of ISL will be sought.

6. **Recommendation:** Provide key support staff to assist the research scientists on a timely basis. Provide administrative training in personnel matters to improve effectiveness in recruiting, such as using job fairs.

   Response: Each ISL research scientist is well supported by professional staff. In fact, the number of support staff per SY in ISL is much higher than in most of the laboratories in the Center. The Laboratory manager has obtained some training in recruitment. ISL will put great efforts on recruiting well qualified SY and support scientists.

7. **Recommendation:** Clarify the responsibilities of the National Program Staff and the laboratory manager for priorities and projects. Current roles seem to be in conflict.

   Response: The direction and scope of the ISL research programs are established by NPL and the laboratory manager are to ensure that the laboratory projects are carried out in a most effective way and the objectives of the projects are completed in the set time schedules. The laboratory manager also tries to find the most effective way of utilizing human and fiscal resources assigned to the laboratory. The laboratory manager also periodically briefs the NPL about the progress of the projects in the laboratory.

8. **Recommendation:** Conduct (continue) regular in-laboratory seminars in which one staff member reports on active research, including progress and problems. This might be anything from a formal technical presentation to a planned discussion on a new computer

system, method, or program. These discussions could also include topics that would lead to a more productive laboratory operation. If led by an outside person, this might be a good time to smooth rough edges. This might also help to develop a team approach to all efforts.

Response: In-house seminars are held regularly, and this will be continued on a regular basis.

9. **Recommendation:** Use electronic technologies more effectively for communicating with other ARS and university researchers. In addition to electronic mail, computer networks now allow use of many (specialized or super) computers or specialized instrumentation setups directly from the researcher's office or laboratory.

   Response: Most of the ISL staff can communicate with outside laboratories and institutions via e-mail. The researchers use internet to communicate with colleagues out the laboratory, to download programs and messages from outside sources. The staff also uses the internet to submit abstracts and papers for presentations.

10. **Recommendation:** Place emphasis on anticipating future industry needs as well as providing instrumentation for current needs. Needs may be different by the time current projects are complete.

    Response: Regular meetings with FGIS, FSIS, and AMS have taken place. Also workshops with industry participants have been attended. ISL will continue to be active in technology transfer exchanges with governmental action agencies and private industry.

11. **Recommendation:** Encourage team-building activities to improve the working environment.

    Response: ISL holds regular biweekly staff meetings. Team-building activities will be continued.

12. **Recommendation:** Be sure that each person has opportunities for self-improvement and that each professional-level person maintains contact with professional colleagues outside the lab and in professional organizations. Have a specific plan for this.

    Response: ISL staff members have been and continue to be encouraged to obtain training outside the laboratory. Many have obtained technical and managerial training in the past years. For examples, since Dr. Chen came to ISL as Research Leader in September 1990, Dr. William Hruschka, a mathematician, took a one-day course on "Successful Communication Skills" and a two-day course on "Effective Lighting Engineering for Machine Vision Applications" in 1991, a one-week course on "System Administration" in 1992, a one-semester course in "Neural Nets" in 1993, a one-day course in "PC Hardware" in 1995. Ms. Thelma Brack joined ISL in 1991 as the laboratory secretary. She took a one-day course on "Business Writing Skills" in 1992. In

1993, she took a one-day course on "the Essentials of Credibility, Composure and Confidence Seminar for Women" and one-day course on "How to Get More Organized Using Your PC - A Step-by-Step Guide for Assistants." In 1994, she took a two-day course on "Success Strategies" and in 1995, she took a two-day course on "PC-Tare Training" and a one-day course on "How Secretaries Develop Managerial Skills." ISL will continue its effective use of Individual Development Plans to provide improvement of job-related skills at all levels. All professionals attend two or three professional meetings each year where they interact with colleagues.

13. **Recommendation:** Continue the use of outside mediators to resolve some of the more serious conflicts. Unless these conflicts are dealt with, some key personnel will probably leave.

    Response: Conflicts in ISL have been reduced to a lower level. Representatives of the Employee Assistance Program worked with ISL to improve interactions. Individuals have participated in other team building training. Efforts to develop cooperative attitudes within the laboratory will be continued.

Brief Review Held On January 26, 1995

The following actions were taken in response to the report of the Review Team. The brief review was conducted on January 26, 1995.

1. **Recommendation:** Dr. Delwiche should be encouraged to strengthen ties with the staff in Manhattan, Kansas, and Stewart Nelson in Athens, Georgia.

   Response: Dr. Delwiche has been collaborating much of his research work with the staff at U.S. Grain Marketing and Production Research Laboratory at Manhattan, Kansas. In fact, he is one of the major contributors to a CRADA with Perten Instruments North America at Reno, Nevada. The CRADA was established by the U.S. Grain Marketing and Production Research Laboratory. Since Dr. Delwiche's work has no direct relationship with Stewart Nelson's work, no formal collaboration was established. However, Dr. Delwiche communicates with Stewart Nelson and support scientist Kurt Lawrence several times per year.

2. **Recommendation:** Dr. Abbott should be encouraged to participate in the NE-179 project.

   Response: Dr. Abbott is a member of NE-179 Project. She has attended every NE-179 meeting. In fact, the 1996 NE-179's meeting was held at Beltsville Agricultural Research Center, and Dr. Abbott was one of the organizers.

3. **Recommendation:** In regard to the project on "Rapid, Efficient Detection of Septicemia and Bacterial Contamination in Poultry Carcasses," the review participants suggested that more data needed to be acquired from poultry processing plants. The FSIS representative

felt that the sensors for poultry inspection system should not be in contact with the carcasses and the speed of sensing should be as fast as the processing line speed. The representative also encouraged Dr. Chen to visit Canada to view the similar technology developed by Canadian researchers.

Response: The FSIS representative and ARS NPS representatives were aware of technology for detecting unacceptable poultry carcasses being developed by Agriculture Canada with imaging cameras. Dr. Chen has traveled to Canada to view the Canadian technology on-site once. Plans were made to travel to Canada to view the technology again. However, Agriculture Canada was not able to accommodate the visit date. Because of proprietary concerns, there was no information on their progress and FSIS had difficulty making further arrangement for our visit to Canada to view the technology on-site. Dr. Chen will continue to find the opportunity to visit Canada. Since the Brief Review, Dr. Chen has brought the ISL technology to the point that NIR measurements could be made without contacting the chickens on a moving processing line. In fact, the ISL machine vision poultry carcass inspection system can operate at a line speed of 90 birds per minute, under room light or in darkness, and without contact of any machine parts. Presently, Dr. Chen is assembling an ISL poultry inspection system that is to be installed at a slaughter plant for on-line testing. With a high speed diode array spectrophotometer and high computer systems purchased for slaughter plant use, the new ISL poultry inspection system will be able to operate beyond 90 birds/min.

H. CONTRIBUTIONS FROM SCIENTISTS

I. Name: Judith A. Abbott

Title: Research Horticulturist

II. Education Background:

B.S., Plant Science, Rutgers--The State University, New Brunswick, NJ, 1965
M.S., Horticulture, Rutgers--The State University, New Brunswick, NJ, 1967
Ph.D., Food Science, University of Maryland, College Park, MD, 1983.

III. Employment History:

Career includes 2 years as Research Assistant in a firm developing acoustic spectrometers while working on M.S. and 29 years in USDA at Beltsville: 9 years as a Research Assistant, 3 years as a Support Scientist, and 11 years as a Research Horticulturist in Horticultural Crops Quality Lab and 7 years as Research Horticulturist in ISL. Authored or coauthored over 50 journal publications and 30 abstracts.

IV. Professional Societies:

American Society for Horticultural Science -- Working Group Chair: Food and Nutrition, Postharvest, and Women in Horticulture various times in past 31 years.
American Society of Agricultural Engineers
Gamma Sigma Delta
Sigma Xi, D.C. Chapter -- Board Member and Newsletter Editor, 1995-97.

V. Linkages With Other ARS Laboratories:

BARC:

W.S. Conway and C.Y. Wang, Horticultural Crops Quality Laboratory, BARC, on effects of postharvest calcium, heat, and other treatments of apples. They provide expertise in pathology and physiology, I provide expertise on mechanical and sensory measurement and statistics.

Other Than ARS-BARC:

Bruce L. Upchurch	ARS	Kearneysville, WV
Stephen R. Drake	ARS	Wenatchee, WA
Marvin J. Pitts	Washington State University	Pullman, WA

VI. Publications (for Last 3 Years):

REFEREED JOURNAL ARTICLES

1. Abbott, J.A. 1994. Firmness measurement of freshly harvested 'Delicious' apples by sensory methods, sonic transmission, Magness-Taylor, and compression. J. Amer. Soc. Hort. Sci. 119:510-515.

2. Abbott, J.A., T.A. Campbell, and D.R. Massie. 1994. Delayed light emission and fluorescence responses of plants to chilling. Remote Sensing of Environment 47:87-97.

3. Abbott, J.A., W.R. Forbus, Jr., and D.R. Massie. 1994. Temperature damage measurement by fluorescence or delayed light emission from chlorophyll. ASAE, Proc. BARD Workshop on Nondestructive Technologies for Quality Evaluation of Fruits and Vegetables, Spokane, WA, June 15-19, 1993. pp. 44-49. (Review)

4. Abbott, J.A. and L.A. Liljedahl. 1994. Relationship of sonic resonant frequency to compression tests and Magness-Taylor firmness of apples during refrigerated storage. Trans. ASAE 37(4):1211-1215.

5. Conway, W.S., C.E. Sams, C.Y. Wang, and J.A. Abbott. 1994. Additive effects of postharvest calcium and heat treatment on reducing decay and maintaining quality in apples. J. Amer. Soc. Hort. Sci. 119:49-53.

6. Liljedahl, L.A. and J.A. Abbott. 1994. Changes in sonic resonance of 'Delicious' and 'Golden Delicious' apples undergoing accelerated ripening. Trans. ASAE 37(3):907-912.

7. Pitts, M.J., J.A. Abbott, P.R. Armstrong, G.K. Brown, G.H. Brusewitz, D.C. Davis, M.J. Delwiche, N. Galili, S. Gan-Mor, C.G. Haugh, D.R. Massie, A. Mizrach, D. Nahir, K. Peleg, R.P. Rohrbach, Y. Sarig, P.N. Schaare, Z. Schmilovitch, I. Shmulevich, M.L. Stone, R.L. Stroshine, and F.L. Younce. 1994. Sensing fruit and vegetable firmness. ASAE, Proc. BARD Workshop on Nondestructive Technologies for Quality Evaluation of Fruits and Vegetables, Spokane, WA, June 15-19, 1993. pp. 31-43. (Review)

8. Stroshine, R.L., G.G. Dull, J.A. Abbott, V. Bellon, D. Beaumelle, M. Benady, R. Cavalieri, P. Chen, W.R. Forbus, Jr., N. Galili, A. Mizrach, S. Nelson, Y. Sarig, D. Slaughter, J.E. Simon, and B. Zion. 1994. Nondestructive sensing of internal composition. ASAE, Proc. BARD Workshop on Nondestructive Technologies for Quality Evaluation of Fruits and Vegetables, Spokane, WA, June 15-19, 1993. pp. 97-110. (Review)

9. Abbott, J.A. 1995. Quality measurement by delayed light emission and fluorescence. Proc. Symp. Nondestructive Qual. Eval. Hort. Crops, Intl. Hort. Cong., Kyoto, Japan, 1994. (Review)

10. Abbott, J.A. and D.R. Massie. 1995. Nondestructive dynamic force/deformation

measurement of kiwifruit firmness (*Actinidia deliciosa*). Trans. ASAE 38(6):1809-1812.

11. Abbott, J.A., D.R. Massie, B.L. Upchurch and W.R. Hruschka. 1995. Nondestructive sonic firmness measurement of apples. Trans. ASAE 38(5):1461-1466.

12. Abbott, J.A. and R. Lu. 1996. Anisotropic mechanical properties of apples. Trans. ASAE 39(4):1451-1459.

13. Lu, R. and J.A. Abbott. 1996. A transient method for determining dynamic viscoelastic properties of solid foods. Trans. ASAE 39(4):1461-1467.

14. Lu, R. and J.A. Abbott. 1996. Finite element analysis of modes of vibration in apples. J. Texture Studies 27(3):265-286.

15. Klein, J.D., J.A. Abbott, D. Basker, W.S. Conway, E. Fallik, and S. Lurie. 1996. Sensory evaluation of heated and calcium-treated fruits. Acta Horticulturae (accepted for publication).

NON-PEER REVIEWED

1. Affeldt, H.A., Jr. and J.A. Abbott. 1992. Agricultural commodity condition measurement. U.S. Patent No. 5,152,401.

2. Armstrong, P.R., G.K. Brown, and J.A. Abbott. 1992. Progress on an acoustic technique for estimating apple firmness. ASAE Paper No. 92-6050. pp. 19.

3. Abbott, J.A. and D.R. Massie. 1993. Nondestructive firmness measurement of apples. ASAE Paper No. 93-6025. pp. 9.

4. Abbott, J.A. and R. Lu. 1994. Variation of mechanical properties within an apple. ASAE Paper No. 946604. pp. 18.

5. Lu, R. and J.A. Abbott. 1994. A method for determining dynamic viscoelastic properties of solid foods. ASAE Paper No. 946603. pp. 13.

6. Lu, R. and J.A. Abbott. 1996. Modeling transient responses of apples to acoustic impulses. ASAE Paper 966011. pp. 30.

VII. Current Research Objectives and Past Accomplishments:

CRIS Project Title: Automated Firmness Classification of Apples

Objectives:

We will evaluate optical measurements of soluble solids to develop a robust algorithm for predicting this important quality factor in several commodities. We will develop an automated classification of fruits and vegetables according to the presence of bruises, defects, and decay and by soluble solids content using fluorescence or reflectance imaging.

We propose to combine defect detection and nondestructive sensing of soluble solids into classification indexes for real-time sorting of fruits and vegetables (apples, cucurbits, peaches and nectarines, pears, and tomatoes). We propose initially to automate detection of surface defects using visible, NIR, or fluorescence imaging technologies. We will simultaneously implement NIR measurement of soluble solids for those commodities in which it is an important flavor constituent. We will later attempt to implement internal defect detection. Preliminary data indicate that chlorophyll fluorescence is suppressed or destroyed by superficial scald and several other defects on apples, pears, tomatoes, and citrus. Several fruit pathogens fluoresce and can readily be detected from fluorescence images. Other fluorescing compounds may be present in sufficient quantity in some fruits and vegetables to be useful for detecting particular conditions.

Accomplishments:

Sonic Firmness measurement: We developed a nondestructive sonic measurement to classify the firmness of fruit. The fruit packing industry urgently needs sensing methods for quality attributes that are automated sorting. Fruits and vegetables are notoriously variable, and the quality of individual pieces may differ greatly from the average of a grower lot. Packers need to sort these mixed lots into very uniform sublots to meet various grades and standards. To maximize quality of a lot, the packer needs to examine and make a quality judgment on every individual piece of produce within the lot and to sort out those individual pieces that are substandard. There is usually economic incentive to further classify the satisfactory produce into several grades. Firmness is a critical quality attribute, particularly for fresh market apples, and there is no method available at present for detecting firmness of fruit without damaging or destroying the product. The industry standard measurement is the destructive Magness-Taylor penetrometer test.

Apples: When consumers manually evaluate firm fruits like apple, they tend to bruise them, testing ultimate strength. Magness-Taylor tests ultimate strength of apple tissue. Sonic vibrations measure elasticity; however, elastic properties and strength are structurally related (about $r = 0.8$ in apples) and it was hoped that sonics would provide a nondestructive estimate of firmness to predict the destructive test values. Sonic transmission amplitudes, rates of transmission, and resonant frequencies were examined as possible nondestructive means to measure firmness of apples. We found that sonic resonant frequency was more closely related to the modulus of deformability than to the traditional Magness-Taylor value, consistent with theory. Rate of sonic transmission did not vary enough to provide discrimination. Combinations of amplitudes at selected frequencies were no better than, and were generally not as good as, resonant frequencies for predicting penetrometer maximum force. The size of the fruit affects the resonant frequency and we confirmed that the sonic stiffness coefficient proposed earlier compensated for the size effect. Correlations of sonic stiffness coefficients to

Magness-Taylor were not generally high enough for satisfactory prediction at the tolerance that the apple industry specified. However, we developed an algorithm using the sonic stiffness and other data related to the shape and location of resonances which could classify apples as firm or soft with about 80 to 85% accuracy for most lots. Both prediction and classification were better for symmetrically shaped apples such as 'Golden Delicious' than for the more irregular 'Delicious.' In lots of apples that fail to meet firmness standards but where many of the fruit are firm, this level of sorting would enable packers to obtain fresh-market prices for a significant portion of the lot instead of selling the entire lot to a processor for much lower price.

Computer Simulations: The sonic method for nondestructive measurement of apple is based on measurement of resonant frequencies under sonic vibration. To understand the principle of measurement and to enhance instrument design, we developed computer simulations to study the vibrational characteristics of apples and factors affecting sonic measurement. We developed three-dimensional computer models to describe apples with different shapes and sizes. Simulations show three basic classes of vibration modes. The first resonance is related to instrumentation. The second and third resonant frequencies are related to the apple's elastic modulus, size, and shape. The square of resonant frequency was linearly related to Young's modulus of elasticity, a measure of firmness. Shape influenced resonant frequencies of all modes. Inclusion of a shape factor in the measurement should improve firmness prediction; however, empirical tests did not demonstrate improvement when simple shape ratios were included in the model. The contact material, contact area between the fruit and instrument, and the input signal influence the vibrational characteristics of an apple but do not affect the second and third resonant frequencies. Optimal instrument design can be achieved by selecting a contact material slightly softer than apples, using a relatively large contact area, and using an impulse whose highest frequency is approximately equal to the maximum frequency of interest.

Kiwifruit: When consumers manually evaluate soft fruits like kiwifruit or stone fruits, they squeeze gently, measuring elasticity. When they evaluate firm fruits like apple, they tend to bruise them, testing ultimate strength. Sonic vibrations measure elasticity; therefore we believed that sonics would be suitable for measuring kiwifruit firmness objectively. We compared sonic vibrational responses of kiwifruit over the range 0 to 2000 Hz to the industry standard firmness measurement, the Magness-Taylor (MT) penetrometer test. The sonic measurements were closely related to the MT values. Sonic stiffness coefficients, based on sonic resonant frequencies and mass of the fruit, provided good to excellent classification of kiwifruit into two or three firmness categories based on MT maximum force values. A combination of amplitudes at several specific sonic frequencies also provided successful classification. Identification of soft kiwifruit was 89 to 96% accurate; and of firm kiwifruit, 83 to 91%. These results clearly indicate the potential for nondestructive firmness sorting based on sonic frequency vibrations.

I. Name: Yud-Ren Chen

Title: Supervisory Agricultural Engineer

II. Educational Background:

1958-62 National Taiwan University; major, Mechanical Engineering; B.S. 1962
1964-66 University of Rochester; major, Mechanical and Aerospace Sciences; M.S. 1966
1966-69 University of Rochester; major, Mechanical and Aerospace Sciences; Ph.D. 1970

III. Membership in Professional Societies:

American Society of Agricultural Engineers
Institute of Electrical and Electronic Engineers, Inc.
Society of Applied Spectroscopy

IV. Editorial Advisory Boards:

Computers and Electronics in Agriculture
Bioresource Technology

V. Honors and Awards:

Member, Sigma Xi
USDA Certificates of Merit, April 20, 1989.
USDA Certificates of Merit, July 13, 1989.
USDA Invention Award, July 15, 1990
USDA ARS Special Act or Service Award, December 1, 1991
USDA ARS Special Act or Service Award, October 2, 1992
USDA ARS Outstanding Performance, Within-Grade Increase, 1994
USDA ARS Performance Award, 1995

VI. Professional Employment:

1970-1973 Assistant Professor, Physics and Mathematics, Paine College, Augusta, Georgia

1971 and 1972 Summers, Agricultural Engineer, USDA, ARS, Cornell University, Ithaca, New York

1973-1976 Agricultural Engineer, USDA, ARS, Cornell University, Ithaca, New York

1976-1987 Agricultural Engineer, USDA, ARS, U.S. Meat Animal Research Center, Clay Center, Nebraska

1977-1990 — Adjunct Assistant and later Associate Professor, Agricultural Engineering, University of Nebraska, Lincoln, Nebraska

1987-1990 — Research Leader, Biological Engineering Research Unit, USDA, ARS, Roman L. Hruska U.S. Meat Animal Research Center, Clay Center, Nebraska

1990-present — Research Leader, Instrumentation and Sensing Laboratory, USDA, ARS, Beltsville Agricultural Research Center, Beltsville, Maryland

VII. Foreign Invitations:

Dr. Chen was invited to present seminars at several professional meetings and to lecture on and consult about research at universities and research institutes in the United States and in foreign countries. Following are his major foreign invitations:

1. Presented a seminar on anaerobic fermentation of livestock wastes at the Chemical Engineering Department, Cheng Kung University, Tainan, Taiwan, July 30, 1979.

2. Lectured on the subject entitled "Biogas Digester Design, Operation, and Slurry Utilization" at the Technical Workshop-Symposium on Fuels and Chemicals From Biomass Through Fermentation, San Jose, Costa Rica, February 16-18, 1981

3. Lectured on the kinetics of anaerobic digestion and biogas digestion design methods to the graduate students and faculty at the Research Institute of Chemical Engineering, South China Institute of Technology, Canton, People's Republic of China, November 7-9, 1985.

4. Lectured on anaerobic treatment of organic wastes at the Annual Meeting of Guangton Provincial Association of Soil and Water Conservation, Canton, People's Republic of China, November 8, 1985.

5. Lectured on biogas digester design fundamentals to the First Training Class of Biogas Production, sponsored by Chinese Center of Rural Energy Research and Training, Rural Energy Department, Chinese Academy of Agricultural Engineering Research and Planning, Beijing, People's Republic of China, November 21, 1985.

6. Presented a series of lectures on anaerobic fermentation of agricultural residues at Sheng-Yang Agricultural University, Sheng-Yang, China, November 25-27, 1985.

7. Lectured at the Automation of Rice Processing Workshop held in Taichung, Taiwan, June 6-12, 1993.

8. Lectured at the Workshop on Nondestructive Quality Inspection for Rice held in Taipei, Taiwan, May 17-18, 1994.

9. Presented seminars at the Korean Food Research Institute, Seoul National University, and Sung Kyun Kwan University in Korea, November 10-12, 1994.

10. Presented an invited lecture entitled "Agricultural Products Quality Assessment and R & D Activities in USDA/ARS" at the International Symposium on Quality Evaluation of Agricultural Products and Foods Using Nondestructive Techniques. Seoul, Korea, November 16, 1996.

VIII. Cooperators:

<u>**Non-ARS**</u>

Larry E. Stewart	University of Maryland	College Park, Maryland
Wilfred H. Nelson	University of Rhode Island	Kingston, Rhode Island
Shaukat Syed	FSIS	Washington, D.C.
Frank Gwozdz	FSIS	Washington, D.C.

<u>**ARS**</u>

G. LeRoy Hahn	ARS	Clay Center, Nebraska
Mohammad Koohmaraie	ARS	Clay Center, Nebraska
Morse Solomon	ARS	Beltsville, Maryland

<u>**Foreign Scientists**</u>

Heon Hwang	Sung Kyun Kwan Univ.	Suwon, Korea
Chang-Hyun Choi	Sung Kyun Kwan Univ.	Suwon, Korea
Doo Ho Chung	Rural Develop. Adm. Korea	Suwon, Korea

IX. Publications (for Last 3 Years):

<u>REFEREED JOURNAL ARTICLES</u>

1. Park, B. and Y.R. Chen. Intensified multi-spectral imaging system for poultry carcass inspection. *Trans. of the ASAE.* Vol. 37(6):1983-1988. 1994.

2. Park, B., Y.R. Chen, A.D. Whittaker, R.K. Miller, and D.S. Hale. Neural network modeling for beef sensory evaluation. *Trans. of the ASAE.* Vol. 37(5): 1547-1553. 1994.

3. Chen, Y.R., S.R. Delwiche, and W.R. Hruschka. Classification of hard red wheat by feedforward backpropagation neural networks. *Cereal Chemistry.* 72(3):317-319. 1995.

4. Park, B. and Y.R. Chen. Intensified multi-spectral imaging system for poultry carcass inspection. *Trans. of the ASAE.* Vol. 37(6):1983-1988. 1995.

5. Delwiche, S.R., Y.R. Chen, and W.R. Hruschka. Classification of hard red wheat by near-infrared analysis of bulk samples. *Cereal Chemistry*. Vol. 72(3):243-247. 1995.

6. Song, H.P., S.R. Delwiche, and Y.R. Chen. Neural network classification of wheat using single kernel near-infrared transmittance spectra. *Journal of Optical Engineering*. 1995. (In press).

7. Chen, Y.R., R.W. Huffman, and B. Park. Changes in the visible/NIR spectra of chicken carcasses in storage. Journal of Food Process Engineering. *Journal of Food Process Engineering*. Vol. 19: 121-134. 1996.

8. Chen, Y.R., R.W. Huffman, B. Park, and M. Nguyen. Transportable spectrophotometer system for on-line classification of poultry carcasses. *Journal. of Applied Spectroscopy* 50(7): 910-916. 1996.

9. Park, B. and Y.R. Chen. 1996. Multispectral image co-occurrence matrix analysis for poultry carcass inspection. *Trans. of the ASAE.* 39 (4): 1485-1491.

10. Park, B., Y.R. Chen, M. Nguyen, and H. Hwang. Characterizing multispectral images of tumorous, bruised, skin-torn, and wholesome poultry carcasses. *Trans. of the ASAE* 39 (5): 1933-1941. 1996.

11. Park, B., Y.R. Chen, and R.W. Huffman. Integration of visible/NIR spectroscopy and multispectral imaging for poultry carcass inspection. *Journal of Food Engineering*. 1996. (In press).

12. Park, B. and Y.R. Chen. Ultrasonic shear wave characterization in beef *Longissimus* muscle. *Trans. of the ASAE.* 1996. (In press).

13. Hwang, H., B. Park, M. Nguyen, and Y.R. Chen. Hybrid image processing for robust extraction of lean tissues on beef cut surface. *Computers and Electronics in Agriculture.* 1996. (In press).

14. Chen, Y.R., R.W. Huffman, M. Nguyen, and B. Park. Classification of on-line poultry carcasses with backpropagation neural networks. *Journal of Food Process Engineering.* 1996. (in review)

15. Park, B. and Y.R. Chen. Multispectral image analysis using neural network algorithm. *Journal of Agricultural Engineering Research.* 1996. (in review)

16. Korthals, R.L., Y.R. Chen, G.L. Hahn, and R.A. Eigenberg. Calculation of fractal dimension from cattle thermoregulatory responses. *Journal of Thermal Biology*. 1996. (in review)

PROCEEDINGS

1. Park, B. and Y.R. Chen. Intensified multi-spectral image system for poultry carcass inspection. Food Processing Automation Conference III:97-106. 1994. Orlando, FL.

2. Park, B. and Y.R. Chen. Ultrasonic shear wave characterization in beef *Longissimus* muscle. Proceedings of the Food Processing Automation IV Conference, 3-5 November 1995, Chicago, Illinois pp. 248-258.

3. Hwang, H., B. Park, M. Nguyen, and Y.R. Chen. Neuro-based intelligent separation of fat and lean tissue on beef cut surface. Food Engineering Conference. Dec. 2-4, 1995. Chicago, IL.

4. Chen, Y.R. Agricultural product quality assessment and R & D activities in USDA/ARS. Proceedings of the International Symposium on Quality Evaluation of Agricultural Products and Foods Using Nondestructive Techniques. Seoul, Korea. pp. 20-41. 1996. (Invited Paper)

5. Hwang, H., B. Park, M. Nguyen, and Y.R. Chen. Hybrid image processing for robust extraction of lean tissues on beef cut surface. *SPIE* 2665: 231-241. 1996.

6. Hwang, H., Y.K. Lee, and Y.R. Chen. Robust extraction of lean tissue contour from beef cut surface image. Proceedings of the International Conference on Agricultural Machinery Engineering '96. November 12-15, 1996. Vol. 3. Korea Exhibition Center (KOEX), Seoul, Korea. pp. 780-791. 1996.

7. Park, B. and Y.R. Chen. Multispectral imaging application for food inspection. Proceedings of the International Conference on Agricultural Machinery Engineering '96. Vol. 3. November 12-15, 1996. Korea Exhibition Center (KOEX), Seoul, Korea. pp.755-764. 1996.

8. Chen, Y.R., B. Park, M. Nguyen, and R.W. Huffman. Instrumental system for on-line inspection of poultry carcasses. International Symposium on Lasers, Optics, and Vision for Productivity in Manufacturing I, SPIE Vol. 2786: 121-129. 1996.

TECHNICAL REPORTS

1. Chen, Y.R., B. Park, and R.W. Huffman. Instrument inspection of poultry carcasses. ASAE Paper No. 946026, ASAE, St. Joseph, Michigan. 1994. (Technical Research Report)

2. Park, B. and Y.R. Chen. Multi-spectral image textural analysis for poultry carcass inspection. ASAE Paper No. 946027. ASAE, St. Joseph, Michigan. 1994.

3. Park, B., Y.R. Chen, and M. Nguyen. 1996. Multispectral image analysis using neural network algorithm. ASAE Paper No. 963034. ASAE, St. Joseph, MI.

X. Current Research Objectives and Past Accomplishments:

CRIS Project Title: Development of Techniques for Instrument Grading of Inspection of Meat and Poultry Carcasses

Objectives:

Current research objectives are to develop an automated, real-time system for on-line detection of unwholesome poultry carcasses (as defined by the Food Safety Inspection Service). The goals are to make the system robust, effective, low cost, and fast. These include devising robust, fast algorithms that will be able to effectively separate unwholesome carcasses from the wholesome carcasses and that the system can be used in the slaughter plant environment. Other objectives of research are: to develop nondestructive, noninvasive, rapid methods for the measurement of beef lean yield and quality parameters, such as tenderness, marbling, juiciness, and rib-eye size, to develop instrumentation for nondestructive determination of the composition and tenderness of beef carcasses using near-infrared (NIR) technique, and to develop instrumentation and algorithms for nondestructive determination of the composition, backfat thickness, intramuscular fat content, and tenderness of beef carcasses using ultrasonic A-mode speed, attenuation, and frequency analyses, and ultrasonic B-mode imaging techniques.

Accomplishments:

Poultry: A visible/near-infrared (Vis/NIR) spectrophotometer system was tested for on-line classification of wholesome and unwholesome carcasses. Vis/NIR spectra of wholesome and unwholesome poultry carcasses on a moving shackle were obtained using a spectrophotometer system, either under the room light or in a dark environment. The unwholesomeness included cadaver, septicemia, airsacculitis, bruise, ascites, and tumor. The shackle speed was set either at 60 or 90 birds/min and the distance between the probe and the carcass was set within 2 to 5 cm. The scanning time was 0.32 seconds per carcass.

Neural network models and PCA/MD (Principal Component Analysis/Mahalanobis Distance) classifiers were developed on a calibration set and validated on a test set, which did not include any samples from the calibration set. All models showed that the Vis/NIR spectrophotometer system could classify the wholesome or unwholesome carcasses with accuracies higher than 94%. The best results were obtained with the 90 birds/min shackle speed and sensing in dark. The accuracies were 96.0% for classifying wholesome carcasses and 98.9% for unwholesome carcasses. The results also showed that the room light intensity was too low, compared to the spectrophotometer system's tungsten halogen light source, to make any impact on the measurement. All these results indicated that the Vis/NIR spectrophotometer system can be used for on-line, real-time classification of wholesome and unwholesome carcasses with very high accuracy.

A multiple spectral imaging technique was also tested for the separation of wholesome and unwholesome carcasses. The system acquires spectral images from the chicken on a moving

shackle in real-time and processes these spectral data for classification. The spectral images of 540 nm and 700 nm wavelengths were useful for separating unwholesome carcasses (including ascites, airsacculitis, bruise, cadaver, leukosis, septicemia, and tumor) from the wholesome carcasses based on spectral image pixel intensity and the intensity distribution of Fourier power spectrum. The best neural network classifier was obtained when spectral image pixel intensity of 540 nm and 700 nm wavelengths were combined and used as inputs. The accuracy of validation was 93.3%.

A pilot-scale instrumental inspection system for poultry carcasses was assembled and tested. The system includes a Vis/NIR spectrophotometer system for scanning the breast of the bird and a spectral imaging system which consists of two cameras with 540 and 700 nm filters for imaging the front of the bird and two additional cameras with identical filters for imaging the back of the bird. This pilot-scale system can operate 62 birds moving at a speed up to 100 birds per minute. Presently, both of the Vis/NIR system and the spectral imaging system can operate up to 100 birds per minute. As of this date, three high speed personal computers (a 166-MHz and two 200-Mhz pentiums) and one high speed spectrophotometer (10 times faster than the current system) are ordered and to be implemented in the near future. As a result of the higher processing speed equipment, the speed of instrumental inspection could be greatly increased.

Beef: An ultrasonic instrument for meat tenderness measurement non-invasively was designed and fabricated. Using this equipment, the ultrasonic longitudinal and/or shear velocities, which is a function of elastic modulus of muscle tissue, were measured. NIR reflectance characteristic of meat was investigated at the wavelength 1100-2500 nm using 70 difference tenderness meat samples. A partial least squares regression model to predict tenderness of the beef was developed, with the determination coefficient (R^2) of the model to be 0.87. This research will benefit FSIS, AMS, poultry and beef industries.

CRIS Project Title: Nondestructive quality evaluation of fruits

Objectives:

Current research objectives are to develop a machine vision system to classify size, color, and damages of fruits, using visible/NIR spectrophotometry and multispectral imaging techniques.

Accomplishments:

This is a joint project newly established between ARS and the National Agricultural Mechanization Research Institute in Korea to develop instrumentation for multispectral imaging and near-infrared (NIR) spectrophotometry for fruit quality evaluation. The visible/NIR reflectance (400-2500 nm), soluble solids, and Magness-Taylor (MT) firmness of 940 Washington 'Delicious' apples were measured. The results showed that, for the Washington 'Delicious' Apples, there was a high correlation between their soluble solids and NIR reflectances. The correlation between the predicted and measured soluble solids for the calibration set was 0.95, when the wavelength range of 860-1080 nm and 10 factors were

chosen. The root mean squared deviation was 0.34. The correlation between the predicted and measured MT firmness was low. Measurements of the visible/NIR reflectance, soluble solids, and MT firmness of Pennsylvania 'Gala' apples are in progress. The fruit producers, packers, and consumers will benefit from these studies which will lead to successful development of apple quality sensors.

I. Name: Stephen R. Delwiche

Title: Agricultural Engineer

II. Educational History:

1974-1978 Cornell University; Agricultural Engineering; B.S., 1978.

1980-1982 North Carolina State University; Biological and Agricultural Engineering; M.S., 1982.

1985-1990 Cornell University; Agricultural and Biological Engineering; Ph.D., 1990.

III. Post-Graduate Employment History:

1990-present Agricultural Engineer, Instrumentation and Sensing Laboratory, BARC, ARS, USDA, Beltsville, Maryland.

1985-1990 Teaching Assistant, Research Assistant, USDA Trainee, Department of Biological and Agricultural Engineering, Cornell University.

1983-1985 Research Support Engineer, USDA-ARS, Coastal Plain Experiment Station, Tifton, Georgia.

1980-1982 Research Assistant, Department of Biological and Agricultural Engineering, North Carolina State University.

1978-1980 Civil Engineer, USDA, Soil Conservation Service, Grand Rapids, Michigan.

IV. Professional And Honor Societies:

American Society of Agricultural Engineers (ASAE)
American Association of Cereal Chemists (AACC)
Association of Official Analytical Chemists, International (AOAC)
Sigma Xi
Gamma Sigma Delta

V. Committee Memberships:

Chair, Near-Infrared Analysis Technical Committee, AACC, 1993-present.
Associate Referee, Commodity Foods and Commodity Products Methods Committee, AOAC International, 1995-present.
Invited by AACC President to serve on Scholarship Committee of Association, 1996.
Radiation Committee, ASAE, 1990-present.

NC-213 Regional Committee, Marketing and Delivery of Quality Cereals and Oilseeds, 1991-present.

VI. Professional Reviewer Activities:

Member of Editorial Board for *Cereal Chemistry,* 1994-present.
Reviewer for *Cereal Chemistry, Transactions of the ASAE, Journal of AOAC International, Journal of Agricultural and Food Chemistry, Journal of Near Infrared Spectroscopy.*
Review Panel Member for USDA-SBIR Grant Proposals, 1996 and 1997.
Reviewer of USDA-CSRS, US-AID, and USDA-BARD proposals, 1990-1996.

VII. Outside Funding:

Received 1993 Competitive Administrator/Headquarters-funded ARS Postdoctoral Research Associate ($43,000).
USDA NRI Grant no. 95-37500-1927, "Wheat Kernel Moisture During the Pre-Milling Stage of Tempering," 1995-1997 ($142,000).

VIII. Cooperators:

Non-ARS

Dr. Kent S. McKenzie, California Cooperative Rice Research Foundation, Inc., Biggs, California.

Dr. Nam Sun Wang, Department of Chemical Engineering, University of Maryland, College Park, Maryland.

Mr. Glen Weaver, ConAgra Milling, Inc., Omaha, Nebraska.

Dr. Philip C. Williams, Grain Research Laboratory, Canadian Grain Commission, Winnipeg, Manitoba, CANADA.

ARS

Dr. Elaine T. Champagne, Southern Regional Research Center, New Orleans, Louisiana.

Dr. Okkyung K. Chung, U.S. Grain Marketing and Production Research Laboratory, Manhattan, Kansas.

Dr. Anna M. McClung, Rice Quality Laboratory, Beaumont, Texas.

Dr. James B. Reeves, III, Nutrient Conservation and Metabolism Laboratory, Beltsville, Maryland.

IX. PUBLICATIONS (for Last 3 Years):

REFEREED JOURNAL ARTICLES

1. Delwiche, S.R. and G. Weaver. 1994. Bread quality of wheat flour by near-infrared spectrophotometry: Feasibility of modeling. J. Food Sci. 59:410-415.

2. Delwiche, S.R. 1995. Single wheat kernel analysis by near-infrared transmittance: Protein content. Cereal Chem. 72:11-16.

3. Delwiche, S.R., M.M. Bean, R.E. Miller, B.D. Webb, and P.C. Williams. 1995. Apparent amylose content of milled rice by near-infrared reflectance spectrophotometry. Cereal Chem. 72:182-187.

4. Chen, Y.R., S.R. Delwiche, and W.R. Hruschka. 1995. Classification of hard red wheat by feed-forward back-propagation neural networks. Cereal Chem. 72:317-319.

5. Delwiche, S.R., Y.R. Chen, and W.R. Hruschka. 1995. Differentiation of hard red wheat by near-infrared analysis of bulk samples. Cereal Chem. 72:243-247.

6. Song, H.P., S.R. Delwiche, and Y.R. Chen. 1995. Neural network classification of wheat using single kernel near-infrared transmittance spectra. Optical Engineering 34:2927-2934.

7. Delwiche, S.R., K.S. McKenzie, and B.D. Webb. 1996. Quality characteristics in rice by near-infrared reflectance analysis of whole grain milled samples. Cereal Chem. 73:257-263.

8. Delwiche, S.R. and D.R. Massie. 1996. Classification of wheat by visible and near-infrared reflectance from single kernels. Cereal Chem. 73:399-405.

9. Delwiche, S.R., Chung, O.K., and Seabourn, B.W. 1997. Protein content of hard red winter wheat by near-infrared spectroscopy on whole grain: collaborative study. J. AOAC International (in review).

10. Reeves, J.B. and. Delwiche, S.R. 1997. Determination of protein in ground wheat samples by mid-infrared diffuse reflectance spectroscopy. Applied Spectroscopy (accepted).

11. Delwiche, S.R. 1997. Protein content of single kernels of wheat by near-infrared reflectance spectroscopy. J. Cereal Sci. (in review).

12. Song, H.P., Delwiche, S.R., and Line, M.J. 1997. Moisture distribution in a mature wheat kernel by three-dimensional magnetic resonance imaging. J. Cereal Sci. (in review).

NONREFEREED ARTICLES

1. Delwiche, S.R., P.J. Wan, and M.M. Bean. 1994. Rice amylose content by NIR: Influence of grind rate and humidity. ASAE paper #946052, 21 pp.

2. Song, H.P., S.R. Delwiche, and M.J. Line. 1994. Non-invasive measurement of moisture distribution in individual wheat kernels by magnetic resonance imaging. SPIE Proceedings 2345:414-422.

3. Massie, D.R. and S.R. Delwiche. 1994. A high performance spectrophotometer. SPIE Proceedings 2345:385-391.

4. Delwiche, S.R., K.S. McKenzie, and B.D. Webb. 1995. Grain quality characteristics in rice by near-infrared reflectance of whole grain milled samples. ASAE paper #953614, 15 pp.

5. Delwiche, S.R. 1996. Single kernel protein content in wheat by near-infrared reflectance. ASAE paper #963031, 24 pp.

X. Current Research Objectives and Past Accomplishments:

CRIS Project Title: Assessment of Single Grain Properties for Classification, Grading, and End-use Suitability

Objectives:

Current research objectives are focused on the development of techniques to rapidly measure quality characteristics in wheat and rice, ideally in a nondestructive manner. Visible and near-infrared spectrophotometry are used on single-kernel samples and bulk samples for determination of wheat class, protein content and quality, moisture, hardness, amylose content. In some cases, processing characteristics (e.g., rice starch gelatinization temperature, wheat flour dough mixing time and tolerance) are examined by spectrophotometry; in other cases, end-use properties (e.g., wheat loaf volume and appearance) are also examined. Basic research, involving single-kernel stress/strain behavior, magnetic resonance imaging, and numerical modeling, is currently underway for the purpose of understanding how moisture affects wheat milling performance. We are also interested in understanding the physico-chemical mechanisms underlying starch hydrolysis that affect physical properties (i.e., viscosity) of sprout damaged wheat.

Accomplishments:

Wheat hardness by NIR transmittance: A study was undertaken to determine the feasibility of using near-infrared spectroscopy to determine wheat hardness. It was shown that transmittance readings (740 nm to 1140 nm wavelength range) through single intact kernels were moderately-well correlated to hardness, most likely because of a weak correlation between hardness and vitreousness. Soft wheats tended to have more single kernel hardness variation than hard wheats. Because wheat hardness appears to be caused by the presence and structure of low-molecular-weight endosperm proteins, which are difficult to isolate by spectroscopy, optical hardness measurements will continue as non-perfect until the biochemistry of the endosperm is more fully understood.

NIR for bread quality measurement: Near-infrared (NIR) spectrophotometry was examined as a possible method for the measurement of wheat flour functionality. Three attributes (water absorption, mix time, mix tolerance) which characterize the rheological properties of dough and three (height, grain appearance, overall bake score) which characterize the quality of the baked loaf were measured on pilot-scale equipment. Regression equations that related the NIR spectrum of a flour to each attribute were developed. Our results demonstrated that only one of the six attributes, water absorption, was well-modeled. We believe the success of modeling water absorption was because of the known ability of NIR to measure two properties overall protein content and starch damage which influence water absorption. For the remaining five attributes, NIR spectrophotometry probably lacks the sensitivity necessary for measuring the molecular sub-components of protein, starch, and lipid, which are responsible for functionality.

Single kernel protein content by NIR transmittance: In recent years, the USDA has been seeking to revise U.S. grain standards in order that more emphasis is placed on end-use quality. Traditionally, protein analysis was performed on samples consisting of hundreds, if not thousands, of kernels, most often in ground form. By a technique of near-infrared transmittance spectrophotometry, the spectral signatures of single wheat kernels have been related to their protein contents. All six major classes of wheat grown in the United States were examined. The mathematical models developed for predicting single kernel protein content from a spectrum demonstrated reasonably high accuracy. Typically, spectrally-determined kernel protein content could be predicted to within +/- 1.5 percentage units more than 95% of the time. Such ability should prove useful to wheat breeders by providing a nondestructive method for selecting genetic lines which possess desirable protein characteristics.

Classification of HRW and HRS by NIR on bulk samples: The two predominant classes of wheat grown in the United States that are used in bread-making are hard red winter (HRW) and hard red spring (HRS). Subtle perceived differences in the processing and baking characteristics often result in a difference in trade price of the classes. Often, both wheats are very similar in appearance, making it extremely difficult for inspectors of the U.S. Federal Grain Inspection Service (FGIS) to distinguish them from each other. The grain trade wishes to preserve the current classification structure for wheat. FGIS is seeking an objective method for distinguishing HRW and HRS classes. We have recently reported that classification is possible by near-infrared (NIR) reflectance spectrophotometry on ground samples. The present study has also involved NIR techniques for classification, but has performed them on a bulk-sample basis, thereby eliminating the step of

grinding the grain. More than 2,400 unique wheat samples, grown throughout the central United States over a 4-year period, were used in the study. Four different mathematical classification procedures were evaluated: multiple linear regression (MLR), principal component analysis with Mahalanobis distance (PCA/MD), partial least squares (PLS) analysis, and artificial neural networks (ANN). All four demonstrated that samples could be correctly identified as HRW or HRS at least 88 percent, and more typically, 95 percent of the time. The more complex models demonstrated the ability to accurately classify samples from a new crop year whose samples were not included in calibration.

Factors affecting NIR models for rice amylose content: Amylose content is considered to be the most important factor influencing the cooking and processing characteristics of rice. Previously a procedure was developed at the ISL Beltsville Laboratory for measuring amylose content by near-infrared (NIR) reflectance spectrophotometry, a method that is faster and as accurate as the conventional wet chemistry analytical procedure. The NIR method was performed at tightly controlled levels of humidity and sample grind rate. Consequently, no information was available on the influence of humidity and grind rate until the present study. Rice samples from four varieties spanning a broad range of amylose content were examined at three humidities and three grind rates. The effects were measured on the NIR model predictions of amylose content and on the size of the ground particles. High humidity levels or fast grind rates caused an overestimation of amylose content. Surprisingly, variation in humidity had little effect on particle size distribution, while grind rate had a strong effect. Scientists who develop NIR models for amylose content are advised to maintain their rice samples at low to moderate relative humidity (less than 55%) in order to achieve accurate predictions.

First demonstration of NIR for single kernel classification: Identity of wheat class is an important and necessary component of U.S. trade certificates in domestic and export markets. A rapid and objective technique is needed to classify morphologically similar new wheat varieties which are difficult for human inspectors to distinguish. Previously, we developed a wheat classification procedure that uses the computational procedure, neural networks modeling, on near-infrared (NIR) spectra of ground and bulk samples. Because samples are typically a composite of hundreds of kernels, identification of mixtures of more than one wheat class is not possible. In the current study, neural network models on NIR spectra of single kernels were developed to predict wheat class on a kernel-by-kernel basis. All six unique classes of U.S. wheat were used, with the total number of kernels equaling 2880. For the most general model, incorporating all classes, the average accuracy was 95%. For the models using two classes of data (e.g., hard red winter vs. hard red spring) the accuracies were 97 to 100%. Calibration time was brief; even the most time consuming two-class model could be developed in less than 7 minutes with little loss in accuracy. Prediction of new data was nearly instantaneous. Pending further refinement, the technique could be incorporated into official grading and classification procedures of the FGIS.

Feasibility of 3D MRI of single wheat kernels: The amount of moisture within stored wheat has a direct bearing on its longevity. Excessive amounts (greater than 15% by weight) can foster mold growth while scant levels (less than 7%) may make the grain susceptible to breakage during handling. Moreover, the distribution of moisture within the kernel influences milling performance. Previously, a non-destructive, three-dimensional magnetic resonance

imaging (MRI) was used to measure moisture profiles in corn kernels at elevated (steeping) moisture levels. However, performing such imaging on grains at the lower, i.e., storage-like, moisture levels is more difficult, especially with the smaller grains such as wheat. In the current study, MRI was used for non-invasive measurement of the 3D moisture distribution in single kernels of white winter wheat at 12% moisture. Relying on a custom-made, kernel-sized probe and on carefully selected experimental parameters, a 3D Fourier transform pulse sequence with a short echo time (TE) was used to acquire proton images. The moisture distribution in the starchy endosperm of the wheat was fairly uniform, although the signal was weak. Such knowledge should be of benefit to the wheat milling industry and may help to explain the differences in milling performance among wheat varieties.

Rice quality assessment by NIR on bulk white rice: Various physical and chemical tests exist to assess the cooking and processing characteristics of rice. As new lines of rice are developed in the United States and elsewhere, plant breeders routinely test for amylose content, alkali spreading value (an indicator of the starch gelatinization temperature), protein content, viscosity properties of the flour-water paste, and the appearance of milled kernels (whiteness, transparency, and degree of milling). Although these tests are widely accepted, many are time consuming and require specialized equipment to perform. A previous study demonstrated that near-infrared (NIR) reflectance spectroscopy on ground milled rice samples could accurately measure amylose content and protein content. The follow-up extended this to whole milled samples. Approximately 200 samples of short-, medium-, and long-grain U.S. rices were milled, measured for quality by conventional tests, and analyzed on an NIR spectrometer. Multivariate regression models were developed for prediction of each quality indicator based on the NIR spectrum of a sample. The most accurate models were developed for protein content, amylose content, whiteness, transparency, and milling degree. Intermediate model accuracies were found for alkali spreading value, whereas the viscosity properties were not modeled well.

Single wheat kernel classification by NIR reflectance: Because of the numerous cultivars for the several U.S. wheat classes, segregation by cultivar is generally impractical during post-harvest handling. Cultivars of differing wheat classes are sometimes inadvertently mixed, resulting in the classification of a lot to a mixed category, thus lowering its value. While several methods have been proposed for an objective classification system, near-infrared (NIR) reflectance is one of the most attractive due to its low cost, rapidness, and ease of operation. The current study was conducted to determine the extent to which an NIR based system can classify individual kernels of wheat. More than 300 unique commercial samples representing five U.S. wheat classes, hard red winter (HRW), hard red spring (HRS), soft red winter (SRW), hard white (HWW), and soft white (SWW), were examined in two spectral regions by two custom instruments. The lower wavelength region (551-750 nm) was extremely well suited for distinguishing the color differences between red and white wheats. Within a color group, the longer wavelength region (1100-2500 nm) was moderately well suited for winter vs. spring and hard vs. soft comparisons. Partial least squares and multiple linear regression analyses were used to develop binary decision models for various combinations of two wheat classes. Two-class model accuracy, defined as the proportion of correctly identified kernels of a known wheat class, was greatest (99%) when red and white

classes (e.g., HRW vs. HWW) were compared. Accuracies declined to typically 78-91% when the two classes were of similar color (e.g., HRW vs. SRW, HWW vs. SWW). Using a cascade of binary comparisons similar to two-class models, a five-class model structure was developed. Five-class model accuracy ranged from 65% for soft red winter wheat to 92% for soft white wheat. The USDA Federal Grain Inspection Service, and the wheat trade industry are the intended beneficiaries of this research.

AOAC International Method on protein content in bulk wheat: Collaborative study: Conventional methods for protein content (pc) measurement in cereals are expensive, time-consuming, skilled labor-intensive, and generate hazardous waste. An alternative, ground-grain near-infrared (NIR) spectroscopy, has been used extensively by industry for the past 20 years, owing to the lack of the aforementioned limitations. NIR instruments are now available that measure pc on whole grain, obviating the need for grinding. To become approved by organizations such as the Association of Official Analytical Chemists (AOAC) International and the American Association of Cereal Chemists (AACC), a collaborative study was performed to assess the accuracy, repeatability (within-laboratory precision), and reproducibility (between-laboratory precision) of the NIR methodologies for whole-grain pc measurement. Four types of commercially available NIR instruments were studied which represented various combinations of wavelength region, mode of energy capture, method of energy dispersion, and treatment of spectral data. Results indicate that the whole-grain NIR technique has precision comparable to the two conventional methods, Combustion and Kjeldahl. The accuracy is comparable to the well-accepted levels of ground-grain instruments. With the adoption of an AOAC Official Method and an AOAC Approved Method, this technique will benefit official inspection institutions, analytical laboratories, grain traders and grain processors.

Single kernel protein content by NIR reflectance: Previously, the feasibility of measuring protein content in single kernels of intact wheat by near-infrared (NIR) transmittance was shown by the Beltsville ISL on a small set of samples. In the current research, more than 300 market samples of wheat have been analyzed kernel-by-kernel on a customized near-infrared (NIR) reflectance spectrophotometer. Five of the six major U.S. wheat classes (durum excluded) were analyzed. Regression models were developed to relate NIR reflectance spectra to reference values for single kernel protein content. Results indicate that the NIR reflectance technique is capable of rapid and nondestructive evaluation of single kernel protein content, with an accuracy slightly poorer than the NIR method on bulk samples (the industry standard). The pooling of wheat classes to produce a general model did not diminish model accuracy.

Enhanced MRI of a single wheat kernel at a low (i.e., safe for storage) moisture level: Moisture-tempering is typically performed prior to first break in wheat milling operations to enhance separation of bran, germ, and endosperm. To improve the milling performance and to increase yield, a better knowledge of moisture distribution and migration in individual wheat kernels during tempering is essential. Work at Beltsville has demonstrated the capability of non-destructive measurement of the three-dimensional (3D) distribution of moisture in a single wheat kernel. A 3D Magnetic resonance imaging (MRI) technique was

adapted for the probing of single wheat kernels at storage moistures (ca. 12% w.b.). A 3D projection reconstruction (3DPR) technique was used to acquire high resolution proton density images, whereby the images were related to the 3D moisture distribution in the wheat kernel. At 12% moisture content, the moisture distribution in the starchy endosperm of the wheat was not uniform. The variation of the moisture distribution was from 7.3% to 16.4% (w.b.).

<u>Hydrolysis of wheat starch:</u> Sprout damage in wheat adversely affects baking quality and therefore the trade price for major grain producers world wide. A viscosity-based inspection instrument, known as Falling Number (FN) instrument, has long been used to do rapid and simple screening of sprout damaged grains. We investigated the sources of variability in the FN procedures, and developed a comprehensive mathematical model to gain insight of the mechanisms underlying the role of a sprout activated enzyme, namely alpha-amylase, on the rheological properties of starch solutions during heating. A comprehensive series of FN measurements were conducted to determine the operating-related variability. A mathematical model based on wheat starch sample materials was developed to simulate the important performance parameters of a FN measurement. The model parameters were obtained through separate experiments and a literature survey. Matching closely with the experimental data, the model simulated the instrument performance well.

I. Name: Sukwon Kang

Title: Research Associate/Agricultural Engineer

II. Expertise:

Heat and mass transfer analysis in agricultural engineering and food processing research; Physical properties of food and biological materials; Magnetic resonance imaging.

III. Education:

Ph.D. Agricultural and Biological Engineering, Cornell University, 1996.
M.S. Agricultural Engineering, Seoul National University, 1991.
B.S. Agricultural Engineering, Seoul National University, 1989.

IV. Experience

1996-present	Agricultural Engineer, USDA-ARS, Beltsville, MD.
1995 - 1996	Student Intern, Cornell University News Service
1993 - 1993	Research Assistant, Cornell University.
1992 - 1992	Researcher, Green Engineering, Seoul, Korea.
1991 - 1992	Second Lieutenant, Korean Army, Korea
1989 - 1991	Teaching and Research Assistant, Seoul National University, Korea

V. Societal And Professional Functions

Member, American Society of Agricultural Engineers
Member, Korean Society for Agricultural Machinery
Member, International Association of the Exchange of Students for Technical Experience

VI. Awards And Honors

Summa cum laude, 1989. Seoul National University, Republic of Korea.
University Outstanding Academic Award, 1985-1988. Seoul National University, Republic of Korea

VII. Publications

1. Kang, S. 1996. Development of a Poisson Model to predict recirculating flows in cold storage rooms. Ph. D. Dissertation. Cornell University.

2. Kang, S. and H.K. Koh. 1993. Heat and Mass Transfer Characteristics of Red-Pepper Powder by Convection and/or Radiation Conditioning. Journal of the Korean Society for Agricultural Machinery, 18(1):48-59.

3. Kang, S. 1991. Heat and Mass Transfer Characteristics of Red-Pepper Powder with Hot-air-convective and Infrared-radiant Drying. Master's Thesis. Seoul National University.

4. Kim, M.S., Y.J. Cho, and S. Kang. 1990. Application of an Infrared Drying Process for Red pepper. Journal of the Korean Society for Agricultural Machinery, 15(3):230-243.

5. Koh, H.K., Y.J. Cho, J. B. Park, Y.H. Kim, and S. Kang. 1989. Efficient Utilization of Energy in Drying Process for Rewetted Red Pepper - Hot-air-convective and Infrared-radiant Drying. Journal of the Korean Society for Agricultural Machinery, 14(4): 262-271.

VIII. Current Research Objectives:

CRIS Project Title: Wheat kernel moisture during the pre-milling stage of tempering

Objectives:

The overall objective of this research is to understand the effect of moisture on the physical properties of wheat kernels. The objectives of research activities are (1) to determine the path of moisture within a wheat kernel during the moisture tempering process and to determine the diffusion coefficients for the bran, germ, and endosperm; (2) develop and define a theory on the mechanism of moisture movement inside the kernel, using finite element modeling and data from tempering experiments, magnetic resonance imaging (MRI), and near-infrared (NIR) spectroscopy; and (3) determine the effect of moisture on single kernel milling performance.

Changes in a single corn kernel's moisture distribution and structure during drying have been studied by the MRI method (Song et al., 1992; Song and Litchfield, 1993, 1994). The amount and route of moisture in the corn kernel could determine the distribution and the path of moisture. Recently, we adapted these procedures to measure the moisture distribution in a single wheat kernel (12 percent w.b.). The overall moisture content was typical for ordinary storage conditions.

For mathematical modeling, conventional moisture diffusion models of most cereal grains have used homogeneous components assumptions. Further, simple geometries, e.g., cylinders, spheres, slabs, have been assumed for kernel shapes. Lu and Siebenmorgen (1995) found that models using moisture content as a driving force cannot accurately predict moisture migration in nonhomogenous components of grain. For this model, individual diffusion coefficients for the endosperm, germ, and bran will be used.

I. Name: Renfu Lu

Title: Research Associate/Agricultural Engineer

II. Educational Background:

B. S. in Engineering, Zhejiang Agricultural University, China, 1982
M. S. in Agricultural Engineering, Cornell University, 1987
Ph.D. in Agricultural Engineering, Pennsylvania State University, 1990

III. Experience:

Agricultural Engineer, April 1994 - Present
Instrumentation and Sensing Lab, Beltsville Agricultural Research Center, USDA/ARS
Research Assistant Professor, January 1994 - March 1994
Biological and Agricultural Engineering Department, University of Arkansas
Research Associate, June 1990 - December 1993
Biological and Agricultural Engineering Department, University of Arkansas
Graduate Research Assistant, August 1987 - May 1990
Agricultural and Biological Engineering Department, Pennsylvania State University
Teaching and Research Assistant, February 1982 - July 1985
Agricultural Engineering Department, Zhejiang Agricultural University, China

IV. Professional Society Memberships:

American Society of Agricultural Engineers
Institute of Food Technologists
Alpha Epsilon, the Honorary Society of Agricultural Engineers
Delta Gamma Sigma, the Honorary Society of Agriculture

V. Publications (Since April 1994):

<u>REFEREED JOURNAL ARTICLES</u>

1. Abbott, J.A. and R. Lu. 1996. Anisotropic mechanical properties of apples. Transactions of the ASAE 39(4): 1451-1459.

2. Abbott, J.A., R. Lu, B.L. Upchurch, and R.L. Stroshine. 1996. Technologies for nondestructive quality evaluation of fruits and vegetables. Horticultural Reviews (in press).

3. Lu, R. and J.A. Abbott. 1996. Finite element modeling of transient responses of apples to acoustic impulse. Transactions of the ASAE (in review).

4. Lu, R. and J.A. Abbott. 1996. A transient method for determining dynamic viscoelastic properties of solid foods. Transactions of the ASAE 39(4): 1461-1467.

5. Lu, R. and J.A. Abbott. 1996. Finite element analysis of modes of vibration in apples. Journal of Texture Studies 27: 265-286.

6. Lu, R. and Y.R. Chen. 1996. Characterization of nonlinear elastic properties of beef products under large deformation. Journal of Food Process Engineering (in review).

NONREFEREED ARTICLES:

1. Lu, R. and J.A. Abbott. 1996. Modeling transient responses of apples to acoustic impulse. ASAE Paper No. 966011, Presented at the 1996 ASAE Annual International Meeting in Phoenix, AZ.

2. Abbott, J.A. and R. Lu. 1994. Variation of mechanical properties within an apple. *ASAE Paper No. 946604. Presented at the 1994 ASAE International Winter Meeting in Atlanta, GA.*

3. Lu, R. and J A. Abbott. 1994. A method for determining dynamic viscoelastic properties of solid foods. *ASAE Paper No. 946603. Presented at the 1994 ASAE International Winter Meeting in Atlanta, GA.*

Current Research Objectives:

CRIS No.: 1280-44000-009-00D

Title: Nondestructive Sonic Sensing of Firmness and/or Condition of Apples and Other Agricultural Commodities.

Accomplishments:

We conducted experiments to study fundamental mechanical properties of apples that are directly related to firmness measurement. A new, transient method was developed, which allows the dynamic properties of apples and other solid foods to be determined through one single, transient loading. We performed experiments to measure dynamic viscoelastic properties of apples and potatoes. We studied anisotropic mechanical properties of 'Delicious', 'Golden Delicious', and 'Rome Beauty' apples. We quantified the effects of ripeness and sample location and orientation on mechanical properties of apples. This study provided important data for developing finite element models to simulate and understand the fundamental dynamic behavior of apples under sonic vibrations.

We conducted computer simulations to understand the fundamental principles of sonic sensing methods and the factors affecting firmness measurements. Three-dimensional finite element models were developed to study the vibrational modes in apples and the effects of apple size, shape, composition on resonant frequencies. We also developed finite element models to study the transient responses of apples to sonic impulse. The simulation study allowed us to determine the

relationship between resonant frequencies and apple mechanical properties and to quantify the effect of instrument configuration, input signal, sensor location, and apple geometry and structure on firmness measurement. The simulation results will help us design a better sonic system for effective sorting of apples based on firmness.

CRIS No II.: 1270-42440-004-00D

Title: Development of Techniques for Instrument Grading and Inspection of Meat and Poultry Carcasses

Accomplishments:

We conducted studies to understand the fundamental mechanical properties of beef products in an effort to relate them to beef tenderness measurements. A three-dimensional constitutive equation was developed to characterize mechanical properties of beef products under large deformations. Experiments were conducted to measure nonlinear elastic properties of beef products and to validate the constitutive relationship in a multidimensional loading situation. We found the constitutive equation adequately describes the nonlinear mechanical behavior of beef products and it can be extended to raw and cooked beef; thus allowing us to study the shearing process for tenderness measurement and the factors affecting meat tenderness.

Plans:

Our plans for future research are: a) Extend and modify the existing constitutive equation to characterize nonlinear mechanical behavior of beef. Conduct experiments to measure mechanical properties of raw and cooked beef and to quantify the relationship between beef tenderness and key mechanical properties; b) Perform computer simulations to study the Warner-Bratzler shearing process for measuring tenderness and to determine factors affecting its measurements; and c) Investigate new nondestructive methods, such as mechanical and ultrasonic, for fast and effective measurement of tenderness from raw meat.

I. Name: Bosoon Park

Title: Research Associate/Agricultural Engineer

II. Educational Background:

Ph.D. Agricultural Engineering Department, Texas A&M University, College Station, Texas. 1991.

M.S. Agricultural Engineering Department, Seoul National University, Seoul, Korea. 1984.

B.S. Agricultural Engineering Department, Seoul National University, Seoul, Korea. 1981.

III. Experience:

Postdoctoral Research Associate (September 1991 - August 1992): Agricultural Engineering Department and Food Science Department, Texas A&M University, College Station, Texas

Research Assistant (January 1989 - August 1991): Agricultural Engineering Department, Texas A&M University, College Station, Texas

Teaching Assistant (January 1988 - December 1988): Agricultural Engineering Department, Texas A&M University, College Station, Texas

Project Research Assistant (October 1987 - December 1987): Texas Transportation Institute, College Station, Texas

Graduate Research Assistant (March 1986 - August 1987): Agricultural Engineering Department, Seoul National University, Seoul, Korea

Military Service (September 1984 - October 1985)

Computer System Manager (September 1983 - August 1984)

Instructor (March 1981 - February 1982): Agricultural Engineering Department, Sungkyunkwan University, Suwon, Korea

IV. Special Invitations:

1. Invited to present a seminar on spectral imaging application for food safety assessment at the Korea Rural Development Administration, Suwon, Korea, November 9, 1994.
2. Invited to present a seminar on nondestructive evaluation of agricultural commodities at the Korea Food Research Institute in Sungnam, Korea, November 10, 1994.
3. Invited to present a seminar on imaging technology for food product quality and safety assessment at the SungKyunKwan University in Seoul, Korea, November 12, 1994.
4. Invited to present a seminar on ultrasonic technology for nondestructive food quality evaluation at the International Symposium on Quality Evaluation of Agricultural Products and Food using Nondestructive Techniques in Seoul, Korea, November 16, 1996.

V. Societies, Honors And Awards

American Society of Agricultural Engineers (ASAE)
American Association for Artificial Intelligence (AAAI)
Sigma Xi, the Scientific Research Society
Alpha Epsilon, the Honor Society of Agricultural Engineering
Outstanding Research Award for Exceptional Job Performance from USDA, October 1996

VI. Activities

American Society of Agricultural Engineers (ASAE), Member (1987 - Present)

Serve on the ASAE IET-318 (Flexible Automation and Robotics) technical committee as Chairman (1994 - 1996)
Serve on the ASAE IET-318 (Flexible Automation and Robotics) technical committee as Vice Chairman (1993 - 1994)
Serve on the ASAE IET-312 (Machine Vision) technical committee as Member (1993 - Present)
Serve on the ASAE IET-348 (Radiation) technical committee as Member (1995 - Present)

1. Serve on peer review panel for research manuscript of Transaction of the ASAE
2. Serve on peer review panel for technical research manuscript of American Chemical Society
3. Chairman on the technical presentation session "Robotics Applications & Simulations" for the 1994 ASAE International Summer Meeting, June 19-22, 1994, Kansas City, Missouri.
4. Chairman on the Technical session of Intelligent Agricultural Machines for the 1994 ASAE Winter Meeting on December 13-16, 1994 at Atlanta, Georgia.
5. Chairman on the Technical session of Intelligent System for Automation and Control for the 1996 ASAE Annual International Meeting on July 14-18, 1994 at Phoenix, Arizona.

VII. Publications (for Last 3 Years):

<u>PEER REVIEW JOURNALS:</u>

1. Park, B., A.D. Whittaker, D.E. Bray, and R.K. Miller. 1994. Measuring intramuscular fat in beef with ultrasonic frequency analysis. *J. of Anim. Sci.* 72:117-125.

2. Park, B., A.D. Whittaker, R.K. Miller, and D.S. Hale. 1994. Predicting intramuscular fat in beef longissimus from speed of sound. *J. of Anim. Sci.* 72:109-116.

3. Park, B. and A.D. Whittaker. 1994. Ultrasonic probe design for beef carcass scan. *Trans. of the ASAE* 37(3):965-971.

4. Park, B., Y.R. Chen, A.D. Whittaker, R.K. Miller, and D.S. Hale. 1994. Neural network modeling for beef sensory evaluation. *Trans. of the ASAE* 37(5):1547-1553.

5. Park, B., A.D. Whittaker, R.K. Miller, and D.S. Hale. 1994. Ultrasonic spectral analysis for beef palatability attributes. J. of Food Sci. 59(4): 697-702.

6. Park, B. and Y.R. Chen. 1994. Intensified multispectral imaging system for poultry carcass inspection. Trans. of the ASAE 37(6):1983-1988

7. Chen, Y.R., R.W. Huffman, B. Park, and M. Nguyen. 1996. Transportable spectrophotometer system for on-line classification of poultry carcasses. *J. of Applied Spectroscopy* 50(7): 910-916

8. Chen, Y. R., R.W. Huffman, and B. Park. 1996. Changes in the visible/NIR spectra of chicken carcasses in storage. *J. of Food Process Engineering* 19(2): 121-134

9. Park, B. and Y.R. Chen. 1996. Multispectral image co-occurrence matrix analysis for poultry carcass inspection. *Trans. of the ASAE* 39 (4): 1485-1491.

10. Park, B., Y.R. Chen, M. Nguyen, and H. Hwang. 1996. Characterizing multispectral images of tumorous, bruised, skin-torn, and wholesome poultry carcasses. *Trans. of the ASAE* 39 (5): 1933-1941.

11. Park, B., Y.R. Chen, and R.W. Huffman. 1996. Integration of visible/NIR spectroscopy and multispectral imaging for poultry carcass inspection. *J. of Food Engineering* (In press).

12. Park, B. and Y.R. Chen. 1996. Ultrasonic shear wave characterization in beef *Longissimus* muscle. *Trans. of the ASAE* (In press).

13. Hwang, H., B. Park, M. Nguyen, and Y.R. Chen. 1996. Hybrid image processing for robust extraction of lean tissues on beef cut surface. *J. of Computers and Electronics in Agriculture* (in review).

14. Chen, Y.R., R.W. Huffman, M. Nguyen, and B. Park. 1996. Classification of on-line poultry carcasses with backpropagation neural networks. *Trans. of the ASAE* (in review).

15. Park, B. and Y.R. Chen. 1996. Multispectral image analysis using neural network algorithm. *J. of Agricultural Engineering Research* (in review).

NON-PEER REVIEW JOURNALS:

1. Park, B., Y.R. Chen, A.D. Whittaker, and R.K. Miller. 1993. Neural modeling for predicting beef palatability. *ASAE Paper No. 933047. ASAE. St. Joseph, MI.*

2. Chen, Y.R., R.W. Huffman, and B. Park. 1993. Visible/NIR spectrophotometry for monitoring shelf life of chicken carcasses. *ASAE Paper No. 936067. ASAE. St. Joseph, MI.*

3. Chen, Y.R., B. Park, and R.W. Huffman. 1994. A transportable spectrophotometer system for on-line classification of poultry carcasses. ASAE Paper No. 943577. ASAE St. Joseph, MI.

4. Chen, Y.R., B. Park, and R.W. Huffman. 1994. Instrument inspection of poultry carcasses. *ASAE Paper No. 946026.* ASAE St. Joseph, MI.

5. Park, B. and Y.R. Chen. 1994. Multispectral image textural analysis for poultry carcasses inspection. *ASAE Paper No. 946027.* ASAE St. Joseph, MI.

6. Chen, Y.R. and B. Park. 1994. Adaptive pattern recognition for classifying visible/near-infrared reflection spectra of poultry carcasses. *Food Processing Automation III*, Orlando, FL:401-412.

7. Park, B. and Y.R. Chen. 1994. Intensified multispectral image processing for poultry carcasses inspection. *Food Processing Automation III*, Orlando, FL:97-106.

8. Park, B., Y.R. Chen, and R.W. Huffman. 1994. Integration of visible/NIR spectroscopy and multispectral imaging for poultry carcass inspection. *SPIE* 2345:162-171.

9. Park, B. and Y.R. Chen. 1995. Ultrasonic shear wave characterization in beef Longissimus muscle. *Food Processing Automation IV*:248-258.

10. Hwang, H., B. Park, M. Nguyen, and Y.R. Chen. 1995. Neuro-based intelligent separation of fat and lean tissues on beef cut surface. Food Engineering Conference (CoFE '95), Chicago, IL.

11. Park, B., Y.R. Chen, and M. Nguyen. 1995. Characterizing multispectral images of poultry carcasses. ASAE Paper No. 953604. ASAE St. Joseph, MI.

12. Chen, Y.R., M. Nguyen, and B. Park. 1995. An image processing algorithm for separation of fat and lean tissue on beef cut surface. ASAE Paper No. 953680. ASAE St. Joseph, MI.

13. Hwang, H., B. Park, M. Nguyen, and Y.R. Chen. 1996. Hybrid image processing for robust extraction of lean tissues on beef cut surface. *SPIE* 2665: 231-241

14. Park, B., Y.R. Chen, and M. Nguyen. 1996. Multispectral image analysis using neural network algorithm. ASAE Paper No. 963034. ASAE, St. Joseph, MI.

15. Chen, Y.R., B. Park, M. Nguyen, and R.W. Huffman. 1996. Instrumental system for on-line inspection of poultry carcasses. International Symposium on Lasers, Optics, and Vision for Productivity in Manufacturing I, SPIE Vol. 2786: 121-129.

16. Park, B. and Y.R. Chen. 1996. Multispectral imaging application for food inspection. proceedings of the International Conference on Agricultural Machinery Engineering Vol. 3: 755-764.

VIII. Current Research Objectives and Past Accomplishments:

CRIS Project Title: Development of Techniques for Instrument Grading and Inspection of Meat and Poultry Carcasses

Objectives:

Current research objectives are to develop an automated, real-time system for on-line detection of unwholesome poultry carcasses (as defined by the Food Safety Inspection Service), to develop nondestructive, noninvasive, rapid methods for the measurement of beef lean yield and quality parameters, such as tenderness, marbling, juiciness, and rib-eye size, to develop instrumentation for nondestructive determination of the composition and tenderness of beef carcasses using near-infrared (NIR) technique, and to develop instrumentation and algorithms for nondestructive determination of the composition, backfat thickness, intramuscular fat content, and tenderness of beef carcasses using ultrasonic A-mode speed, attenuation, and frequency analyses, and ultrasonic B-mode imaging techniques.

Accomplishments:

We have tested a multiple spectral imaging system for the separation of wholesome and unwholesome carcasses. The system acquires spectral images from the chicken on a moving shackle in real-time and processes these spectral data for classification. The spectral images of 540 nm and 700 nm wavelengths were useful for separating unwholesome carcasses (including ascites, airsacculitis, bruise, cadaver, leukosis, septicemia, and tumor) from the wholesome carcasses based on spectral image pixel intensity and the intensity distribution of Fourier power spectrum. The best neural network classifier was obtained when spectral image pixel intensity of 540 nm and 700 nm wavelengths were combined and used as inputs. The accuracy of validation was 93.3%.

A spectral imaging system which consists of two cameras with 540 and 700 nm filters for imaging the front of the bird and two additional cameras with same filters for imaging the back of the bird was assembled and implemented at a pilot-scale instrumental inspection system for poultry carcasses. This pilot-scale system can operate 62 birds moving at a speed up to 100 birds per minute.

We developed an algorithm for image processing to segment and quantify ribeye area by machine vision. This algorithm works for robust extraction of lean tissues on beef cut surface. The image processing system which automatically distinguishes lean tissues in the image of a complex beef cut surface and generates the lean tissue contour has been developed. This system utilized an artificial neural network to enhance the robustness of processing. The developed image analysis algorithm showed the feasibility of the human like robust object segmentation and contour generation for the complex, fuzzy and irregular image.

We also designed and fabricated an instrument for ultrasonic shear force measurement for noninvasive beef tenderness evaluation. The equipment is operated semi-automatically. We collected data from a total of 70 samples (Shear force range of from 3.26 to 11.7) for testing system reliability and prediction model development. The ultrasonic experiments gave us the results of ultrasonic velocity correlated the elastic modulus of meat, which could be criteria for beef tenderness.

We conducted an experiment for analyzing near-infrared (NIR) spectroscopic property of beef to evaluate quality including tenderness through reflectance measurement at the wavelength band 1100 - 2500 nm. We compared 'tender' meat to the 'not-tender' meat based on NIR reflectances and their second difference using PLS (Partial Least Square) model to predict meat tenderness. The determination coefficients (R^2) of the models were 0.87 for calibration and 0.33 for validation. Preliminary study indicated that multiple NIR measurements on steaks could be useful for the prediction of tender/tough with success rates approaching 90%.

I. LINKAGES WITH OTHER BA OR ARS LABORATORIES

ISL has worked with the following ARS Laboratories:

- Meat Research Laboratory, BARC, Beltsville, MD
  Collaborating with M.B. Solomon and B.W. Berry on beef quality research.

- Meat Research Unit, MARC, Clay Center, NE
  MRU supplying beef samples and tenderness records and collaborating in research.

- Biological Engineering Research Unit, MARC, Clay Center, NE
  Consulting engineers at BERU, MARC on animal stress research.

- Southern Regional Research Center, New Orleans, Louisiana. (E.T. Champagne)
  Collaborating in rice quality research.

- U.S. Grain Marketing and Production Research Laboratory, Manhattan, Kansas.
  Collaborating with O.K. Chung on wheat quality research.

- Rice Quality Laboratory, Beaumont, Texas. (A.M. McClung)
  Collaborating with Anna M. McClung on rice quality research.

- Nutrient Conservation and Metabolism Laboratory, Beltsville, Maryland.
  Collaborating with J.B. Reeves, III on wheat quality research.

- Poultry Processing and Meat Quality Research Laboratory, Athens, GA
  Engineers in PPMQRL helping ISL to connect to private industry on poultry inspection research.

- Appalachian Fruit Research Laboratory, Kearneysville, WV
  Collaborating with B.L. Upchurch (resigned) on apple firmness research. He provided fruit and collaborated on sonic signal processing.

- Tree Fruits Research Laboratory, Wenatchee, WA.
  Collaborating with S.R. Drake. He occasionally provides fruit and knowledge of the Washington fruit industry.

- Horticultural Crop Quality Laboratory, BARC, Beltsville, MD
  Collaborating with W.S. Conway and C.Y. Wang on effects of postharvest calcium, heat, and other treatments of apples. They provide expertise in pathology and physiology, I provide expertise on mechanical and sensory measurement and statistics.

- Environmental Chemistry Laboratory, BARC, Beltsville, MD
  Using MRI facility and collaboration with their scientists.

DEFINITIONS OF SOME TERMS, ABBREVIATIONS AND ACRONYMS USED IN AGRICULTURAL RESEARCH SERVICE

ARS: Agricultural Research Service. An agency in Research Education, and Economics of USDA. ARS has about 8,057 employees, including about 953 senior scientists. The Agency conducts research at 104 locations in the United States. ARS is led by an Administrator and is divided geographically into eight Areas, which are led by Area Directors.

BA: The Beltsville Area includes the Beltsville Agricultural Research Center, the U.S. National Arboretum, and the Glenn Dale Plant Distribution Station. The Beltsville Area, at 6,600 acres, is the smallest Area geographically, but the largest in terms of personnel and budget. About 1,567 employees, including about 462 scientists, work in the BA.

NPS: National Program Staff. Members are called National Program Leaders and each is a subject matter specialist. NPS serves the Administrator of ARS in developing and coordinating research plans and strategies on a national basis. NPS sets National program directions, establishes priorities, allocates resources, including this review, and acts as a clearing house for decision making. Considerable interaction between Area managers and NPS is required to fulfill our respective roles.

INSTITUTES/CENTERS: The Beltsville Agricultural Research Center is composed of five Institutes or Centers: 1) Plant Sciences Institute, 2) Livestock and Poultry Sciences Institute, 3) Natural Resources Institute, 4) Beltsville Human Nutrition Research Center, and 5) U.S. National Arboretum.

LABORATORIES: Laboratories are units located in the Institutes/Centers. Laboratories are led, both scientifically and administratively, by Research Leaders. Typically, a Laboratory is comprised of 8-10 scientists, a scientific and clerical support staff and several temporary student and postdoctoral employees. The program and mission of a Laboratory of this size must obviously be limited . In reviewing a Laboratory, bear in mind that what appear to be discipline or program gaps are often filled by collaboration with other Laboratories in the BA or elsewhere.

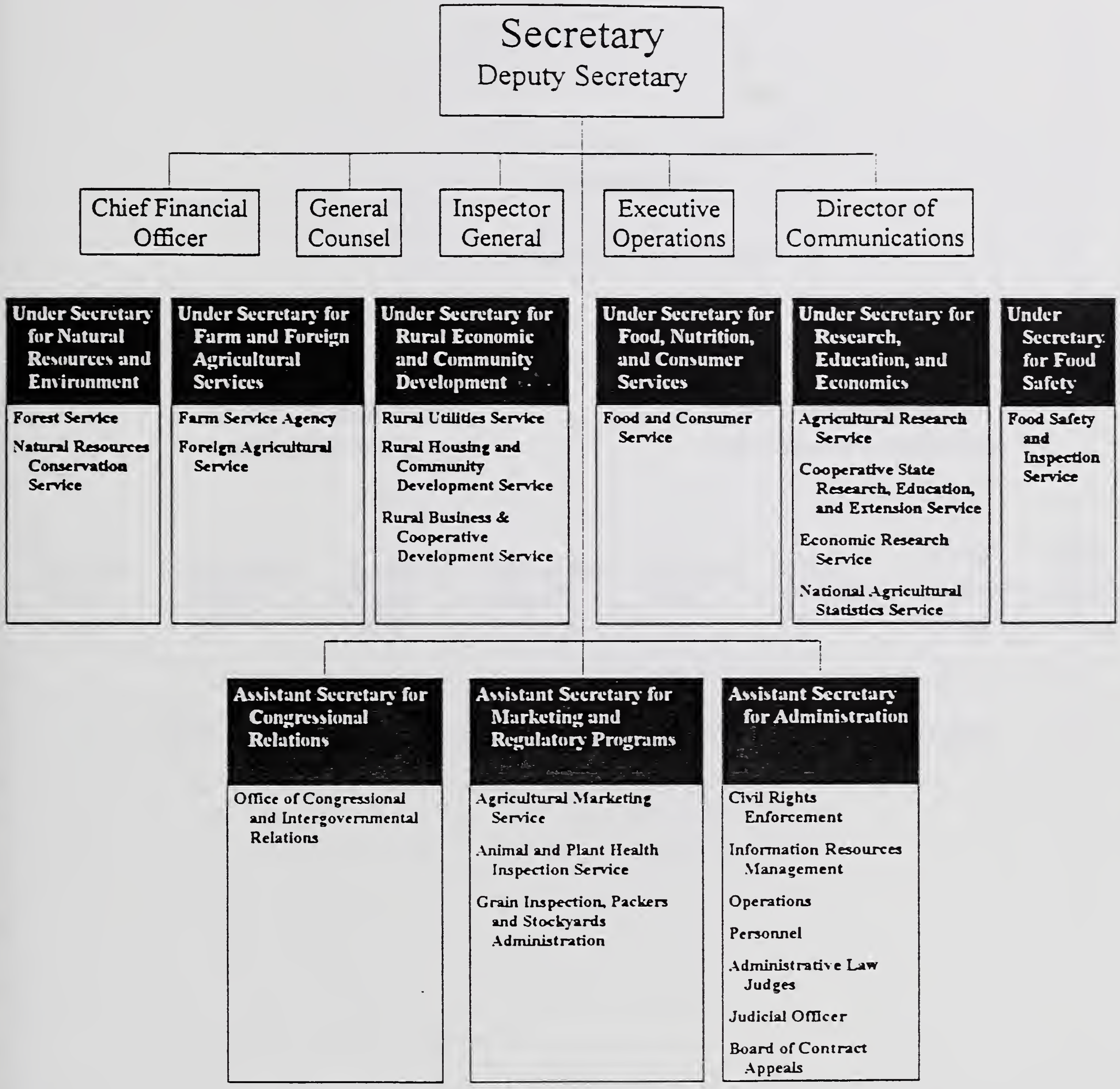
CRIS: Current Research Information System. This is an electronic system for the filing and retrieval of information about individual agricultural research projects. In ARS, the terms "CRIS Work Unit" and the acronym "CRIS" are used synonymously with "research project" or "project." New projects are planned in coordination with NPS and are subjected to peer review. The normal life of a project in ARS is 3 to 5 years.

SY: Scientist Year. This is the effort of a research scientist for 1 year. Fractional efforts (e.g., 0.5 SY) in a given project are possible when a scientist works in more than one project during the course of a fiscal year. The term SY is also used in ARS as a synonym for a research scientist, e.g., "I have six SYs (research scientists) in my Laboratory."

<u>OTHER KINDS OF SCIENTIFIC PERSONNEL</u>: Research scientists are responsible for all phases of research. ARS also employs research associates ("postdocs"), support scientists (who have responsibility for some portion of a project), technicians, students, and in some operations nonresearch scientific personnel who perform work involving service to the public or to other government agencies.

<u>AM</u>: Administrative Management. This branch of ARS manages support activities, such as procurement, facilities, fiscal allocations and personnel operations at all levels in ARS.

NOTE: The organizational scheme described above is presented graphically on the following pages.


Secretary
Deputy Secretary
Chief Financial Officer
General Counsel
Inspector General
Executive Operations
Director of Communications
Under Secretary for Natural Resources and Environment
Forest Service
Natural Resources Conservation Service
Under Secretary for Farm and Foreign Agricultural Services
Farm Service Agency
Foreign Agricultural Service
Under Secretary for Rural Economic and Community Development
Rural Utilities Service
Rural Housing and Community Development Service
Rural Business & Cooperative Development Service
Under Secretary for Food, Nutrition, and Consumer Services
Food and Consumer Service
Under Secretary for Research, Education, and Economics
Agricultural Research Service
Cooperative State Research, Education, and Extension Service
Economic Research Service
National Agricultural Statistics Service
Under Secretary for Food Safety
Food Safety and Inspection Service
Assistant Secretary for Congressional Relations
Office of Congressional and Intergovernmental Relations
Assistant Secretary for Marketing and Regulatory Programs
Agricultural Marketing Service
Animal and Plant Health Inspection Service
Grain Inspection, Packers and Stockyards Administration
Assistant Secretary for Administration
Civil Rights Enforcement
Information Resources Management
Operations
Personnel
Administrative Law Judges
Judicial Officer
Board of Contract Appeals

Agricultural Research Service (ARS)
Administrator
&
Associate Administrator

Deputy Administrator
National Program Staff

Deputy Administrator
Administative Assistant

Pacific West Area*

Northern Plains Area*

Southern Plains Area*

Beltsville Area*

Midwest Area*

North Atlantic Area*

South Atlantic Area*

Mid South Area*

* Each Area is led by an Area Director and an Associate Area Director

Agricultural Research Service – Area Organization

USDA, AGRICULTURAL RESEARCH SERVICE
BELTSVILLE AREA

AREA DIRECTOR
K. D. Murrell

ASSOCIATE AREA DIRECTOR
P. E. Johnson

ASSISTANT AREA DIRECTOR
D. F. Cole

U.S. NATIONAL ARBORETUM
- DIRECTOR — T. S. Elias
- ADMINISTRATIVE & FACILITIES MGR. — L. Baldus (acting)
- EDUCATION & VISITOR SERVICES — J. Walker
- FLORAL & NURSERY PLANTS RESEARCH UNIT — R. Jordan
- GARDENS UNIT — E. Ley

BELTSVILLE HUMAN NUTRITION RESEARCH CENTER
- DIRECTOR — J. Spence
- ASSISTANT DIRECTOR — E. Harris
- DIET AND HUMAN PERFORMANCE — J. T. Judd
- FOOD COMPOSITION — J. M. Harnly (acting)
- METABOLISM AND NUTRIENT INTERACTIONS — J. G. Hallfrisch
- NUTRIENT DATA — J. Holden
- NUTRIENT REQUIREMENTS AND FUNCTIONS — O. E. Levander
- FOOD SURVEYS RESEARCH GROUP — A. Moshfegh

FACILITIES MANAGEMENT & OPERATIONS DIVISION
- DEPUTY AREA DIRECTOR — J. Van De Vaarst
- ADMINISTRATIVE BRANCH — D. Little
- FARM OPERATIONS BRANCH — H. T. Badger
- FACILITY ENG. BRANCH — F. A. Messineo, W. H. Funkhouser, W. Beverley

PLANT SCIENCES INSTITUTE
- DIRECTOR/ASSOCIATE DIRECTOR — B. Leonhardt/R. Korcak
- BEE RESEARCH — H. Shimanuki
- BIOCONTROL OF PLANT DISEASES — R. D. Lumsden
- FRUIT — J. Hartung (Acting)
- HORTICULTURAL CROPS QUALITY — K. Gross
- INSECT BIOCONTROL — E. Dougherty
- INSECT CHEMICAL ECOLOGY — J. Klun
- MOLECULAR PLANT PATHOLOGY — R. E. Davis
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- NEMATOLOGY — D. J. Chitwood
- PLANT MOLECULAR BIOLOGY — A. K. Mattoo
- SOYBEAN AND ALFALFA RESEARCH — D. L. Keister
- SYSTEMATIC BOTANY & MYCOLOGY — A. Y. Rossman
- SYSTEMATIC ENTOMOLOGY — M. B. Stoetzel
- VEGETABLE — K. L. Deahl
- WEED SCIENCE — J. D. Anderson

LIVESTOCK AND POULTRY SCIENCES INSTITUTE
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- ANIMAL IMPROVEMENT PROGRAMS — H. D. Norman
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- GERMPLASM & GAMETE PHYSIOLOGY — L. A. Johnson
- GROWTH BIOLOGY — N. C. Steele
- IMMUNOL. & DISEASE RESISTANCE — J. K. Lunney
- MEAT SCIENCE RESEARCH — M. B. Solomon
- NUTRIENT CONSERVATION AND METABOLISM — B. P. Glenn
- PARASITE BIOLOGY AND EPIDEMIOLOGY — H. R. Gamble
- RESEARCH ANIMAL SERVICES — K. Hummel
- VETERINARY SERVICES — B. Stroud

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- INSTRUMENTATION AND SENSING — Y. R. Chen
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- SOIL MICROBIAL SYSTEMS — P. D. Millner

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It is necessary for employees of U. S. Department of Agriculture, Agricultural Research Service (USDA-ARS), Beltsville Area, to disclose certain "confidential" or proprietary information to ____________________, (hereinafter referred to as the Reviewer), to provide information necessary for the In-depth review of the programs of the ______________________________Laboratory on _______________.

Confidential or proprietary information to be disclosed:___________________________________
____
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The Reviewer shall not disclose the "confidential" or proprietary information to anyone else nor use it for any purpose other than that given above.

This Confidentiality Agreement shall be considered null and void if the Reviewer can demonstrate that: the Reviewer had possession of the information prior to disclosure; (2) the information is generally available to the public in generally available publications at time of disclosure; (3) the information becomes generally available to the public through no fault of the Reviewer after disclosure; or (4) after disclosure, the Reviewer receives the information from a third party having the right to the information and who does not impose a confidentiality obligation upon the Reviewer.

This Confidentiality Agreement shall stay in effect until a patent application has been filed on the confidential information, or for three years, whichever is earlier.

FOR USDA-ARS:	REVIEWER:
Typed Name ______________________________	Typed Name ____________________________
Signature and Date _________________________	Signature and Date _______________________

SCHEDULED AGRICULTURAL RESEARCH PROGRAM REVIEW OR WORKSHOP

INSTRUCTIONS: 1. Submit one planned review or workshop per form. 2. If more space is needed attach additional pages and identify by entry number. 3. Send original to the Deputy Director for Agricultural Research, and copies to participating scientists and appropriate staff and line officials.

FOR ODD USE ONLY
FILE NO.

1. NAME AND ADDRESS OF ORGANIZER

Gary R. Evans, Director
Natural Resources Institute, Beltsville Area
10300 Baltimore Ave., Bg. 003, Rm. 214, BARC-W
Beltsville, MD 20705

PHONE NO. (Include area code)

(301) 504-7338

2. TYPE

- [ ] Multilocation Review
- [x] Single location Review
- [ ] Special Review
- [ ] Workshop

3. PRW ACTION

- [x] Schedule
- [ ] Reschedule
- [ ] Cancel

4. TITLE OF REVIEW OR WORKSHOP

Beltsville Area In-Depth Laboratory Review
Instrumentation and Sensing Laboratory

5. NRP AND CRIS NUMBERS INCLUDED

1270-44000-001-00D; 1270-44000-002-00D; 1270-44000-002-03T; 1270-44000-002-04T; 1270-44000-004-00D; 1270-44000-005-01S; 1270-44000-005-02T; 1270-44000-006-00D

6. LOCATION

Building 303, Conference Room, BARC-East

DATES

February 26, 1997

7. PARTICIPANTS

Laboratory scientists and program leaders; laboratory support staff; NRI Institute Director, representatives from ARS National Program Staff, and Area Director's Office.

8. REASON FOR REVIEW

The laboratory research program is being reviewed to determine progress, accomplishments and problems as well as future direction and needs.

cc:
E. B. Knipling
R. J. Reginato
K. D. Murrell
P. E. Johnson
W. Martinez
F. Ortherfer
J. Craig
R. Gerrits
J. Robens
R. Lawson
Institute/Center Directors
Area Administrative Officer
POB Beltsville Section
Visitor Center

9. DATES OF PREVIOUS REVIEWS (Give NRP, CRIS, and date reviewed)

January 26, 1995, Brief Review

SIGNATURE OF ORGANIZER

Gary R Evans

DATE

1/6/97

Form SEA-20 (Aug 79)

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